GRAVITY AS OBSERVER SYNCHRONIZATION: DERIVING THE GRAVITATIONAL CONSTANT FROM ODTOE FIRST PRINCIPLES

(Gravity as Observer Synchronization: Deriving the Gravitational Constant from ODTOE First Principles)

Formalizing gravity as the fourth information operation on the φ-torus and deriving G through structural invariants

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ANNOTATION

Under the structural hypothesis of pure SYNC self-similarity ($C = B^2$; see §VII.5), this work derives the gravitational constant G without additional fitting parameters within ODTOE (Observer-Dependent Theory of Everything) as a geometric consequence of the informational architecture of reality. Gravity is interpreted as the fourth information operation — SYNC (synchronization) — aligning observers on adjacent recursion levels of the φ-torus. It is shown that configuration inertia $I(C)$ (defined as resistance to reconfiguration) is the geometric foundation of mass, and Newton's force emerges as a result of synchronization pulses between levels with intensity proportional to the product of inertias. A novel formula for G is derived through a self-consistent cubic equation for the recursion depth n, establishing the Planck mass $m_{\text{Pl}} = m_e \cdot \varphi^{2n}$ independently of G (thus breaking the circularity of the standard formula $m_{\text{Pl}} = \sqrt{\hbar c/G}$). The cubic equation for the dimensionless recursion depth n contains only π, φ and architectural integers $9, 3, 2$ (no fitting parameters); the final formula $G = \hbar c/(m_e^2 \cdot \varphi^{4n})$ additionally uses CODATA inputs $\hbar$, c, m_e and the structural hypothesis $C = B^2$. The spectral route through φ-torus mode density and a coherence factor $\Phi_G(\varphi, S, d)$ is presented as heuristic motivation and as a correction to the canonical form in the variable-coherence regime. The equivalence principle is derived from the coincidence of configuration inertias at fixed coherence; composition-dependent deviations $\eta \sim 10^{-16}$ arise as a secondary effect from differences in S between bodies. The paper contains explicit predictions for microgravity experiments with highly coherent systems.

ABSTRACT

Under the structural hypothesis of pure SYNC self-similarity ($C = B^2$; see §VII.5), this work derives the gravitational constant G without additional fitting parameters within ODTOE (Observer-Dependent Theory of Everything) as a geometric consequence of the informational architecture of reality. Gravity is interpreted as the fourth information operation — SYNC (synchronization) — which aligns observers on adjacent recursion levels of the φ-torus. We show that configuration inertia $I(C)$ (defined as resistance to reconfiguration) is the geometric foundation of mass, and Newton's force emerges as a result of synchronization pulses between levels with intensity proportional to the product of inertias. A novel formula for G is derived through a self-consistent cubic equation for the recursion depth n, establishing the Planck mass $m_{\text{Pl}} = m_e \cdot \varphi^{2n}$ independently of G (thus breaking the circularity of the standard formula $m_{\text{Pl}} = \sqrt{\hbar c/G}$). The cubic equation for the dimensionless recursion depth n contains only π, φ and architectural integers $9, 3, 2$ (no fitting parameters); the final formula $G = \hbar c/(m_e^2 \cdot \varphi^{4n})$ additionally uses CODATA inputs $\hbar$, c, m_e and the structural hypothesis $C = B^2$. The spectral route through φ-torus mode density and a coherence factor $\Phi_G(\varphi, S, d)$ is presented as heuristic motivation and as a correction to the canonical form in the variable-coherence regime. The equivalence principle is derived from the coincidence of configuration inertias at fixed coherence; composition-dependent deviations $\eta \sim 10^{-16}$ arise as a secondary effect from differences in S between bodies. The paper contains explicit predictions for microgravity experiments with highly coherent systems.

I. INTRODUCTION: GRAVITY AS SYNCHRONIZATION

Einstein's general theory of relativity [1] describes gravity as the curvature of spacetime under the action of mass-energy. This description is mathematically self-consistent and experimentally confirmed with high precision (see, for example, [2]). However, it leaves three fundamental questions unanswered.

First, why does the gravitational force obey the inverse-square law? General relativity describes this through the linearized solution of Einstein's equations, but that is a necessary mathematical consequence of the equations, not an explanation of their origin.

Second, where does the gravitational constant G come from? When Einstein wrote down his equations in 1915, he chose the coefficient $8\pi G/c^4$ in front of the energy-momentum tensor, but this choice rested on the requirement of agreement with the Newtonian limit. In 1899 Planck [3] noted that the combination of $\hbar$, c, and G forms natural units of mass, length, and time. In classical physics all three quantities were taken as independent measurable constants. However, as will be shown below, in ODTOE each of them is derived from the architecture of the φ-torus: $c = r_0/\tau_0$ (Section II), $\hbar = h(d, S)/2\pi$ (Section V), and G as the result of the SYNC operation (Section VII).

Third, why does the equivalence principle — the fact that inertial mass equals gravitational mass — work so perfectly? In modern physics this is accepted as a fundamental postulate, but no geometric explanation of this fact has been given.

ODTOE (Observer-Dependent Theory of Everything) proposes a fundamentally different approach. In this theory, reality is not described as objective spacetime independent of observers. Instead, reality is a graph of configurations structured as a φ-torus (φ-torus), where each configuration represents a set of observers with a certain mutual coherence $B(O, C)$ (cf. Everett's formulation [4] in terms of relative states). Informational dynamics is implemented through four basic operations: READ (reading, associated with the photon), WRITE (writing, associated with the $W^{\pm}$ bosons), VERIFY (verification, associated with the Z^0 boson), and SYNC (synchronization of coherence between observers — an informational operation functionally analogous to the role of the hypothetical graviton in quantum gravity theory, but realized not as particle exchange, rather as a process of configuration alignment). The idea of information as the foundation of reality goes back to Wheeler's program [5].

The central hypothesis of this work is that *gravity is not a geometric phenomenon but an informational one*. It is a process of synchronizing observers localized on adjacent recursion levels of the φ-architecture. Mass should be interpreted not as an independent property of matter but as configuration inertia — the resistance of a system to transition into a new configuration, proportional to the complexity of the synchronizing process. The connection between gravity and thermodynamics was first established by Jacobson [6].

Within this approach, the inverse-square law arises naturally as a consequence of the accessibility geometry between levels (the D-Protective horizon) and the spectral density of φ-torus modes. The gravitational constant G is no longer an arbitrary parameter, but becomes an expression through the electron mass m_e, the golden ratio φ, and the recursion depth n, determined self-consistently (Section VII):

$$G = \frac{\hbar c}{m_e^2 \cdot \varphi^{4n}} \tag{I.1}$$

where n is the recursion depth that establishes the Planck mass $m_{\text{Pl}} = m_e \cdot \varphi^{2n}$ independently of G through the self-consistent equation (VII.22) (cubic form — (VII.23)). The spectral route through φ-torus mode density and the coherence factor $\Phi_G(\varphi, S, d)$ is a heuristic interpretation (Sections VIII, XIII) and a correction to the canonical form (I.1) in the variable-coherence regime.

Notation convention. In this article, the symbol c everywhere denotes the limiting speed of the actualization front $c = r_0/\tau_0$, derived in [7] from the geometry of the φ-torus. The symbol $\hbar$ denotes the observer-dependent quantum of action $h(d, S)/2\pi$, defined in [8]. In the macroscopic limit ($d = 3$, $S \to 1$), these quantities coincide with the classical values of the speed of light and Planck's constant. However, in ODTOE their origin is fundamentally different: they are not independent input parameters of the theory, but are derived from the unified architecture of the φ-torus.

The structure of the article is as follows. In Section II we briefly review the four ODTOE information operations and give a formal definition of the synchronization operator $\hat{G}$. Section III introduces configuration inertia as a fundamental concept and derives its scaling through the golden ratio. In Section IV we perform dimensional analysis and show how the classical relation $G = \hbar c/m_{\mathrm{Pl}}^2$ arises as the first approximation to the full ODTOE formula. Section V contains the derivation of the Planck mass from the architecture of the φ-torus and the relation between the electron and Planck masses. Section VI develops the physical mechanism of synchronization and shows how Newton's law follows from it. Section VII gives the canonical derivation of G through a self-consistent cubic equation for recursion depth n (equation (VII.22)). Sections VIII-XIII reproduce the heuristic route through the coherence factor Φ_G as an alternative derivation. Section XIV contains reproducible numerical computations with 50-digit structural precision. Sections XV-XXI apply the theory to black holes, cosmology, MOND phenomenology, quantum gravity, and the mass-hierarchy problem. Section XX presents seven experimental predictions as a testing program. The conclusion (§XXV), service sections, and Appendices A-C (§§XXVI-XXVIII) close the article.

II. GRAVITY AS THE FOURTH INFORMATION OPERATION

ODTOE postulates that the dynamics of reality is realized by four basic operations on observer states [9]. Each operation is associated with a specific type of elementary particle and characterized by a specific change in coherence.

READ (γ photon). This is the operation of extracting information about a configuration without changing its coherence structure. Formally:

$$\gamma : |\Psi_d\rangle \to |\Psi_d\rangle + \Delta I \tag{II.1}$$

where ΔI is the informational output (information becomes accessible to the observer, but the configuration remains unchanged).

WRITE (W$^{\pm}$ bosons). This is the operation that changes the configuration, transferring the system into a new state with different coherence:

$$W^{\pm} : |\Psi_d\rangle \to |\Psi'_d\rangle, \quad S(\Psi'_d) \neq S(\Psi_d) \tag{II.2}$$

WRITE is carried out at a rate that depends on configuration inertia: $v(C \to C') = \alpha/(I(C) + \varepsilon)$.

VERIFY (Z^0 boson). This is the operation of checking configuration consistency, which either confirms the configuration or initiates reconfiguration:

$$Z^0 : |\Psi_d\rangle \to \begin{cases} |\Psi_d\rangle & \text{if the configuration is consistent} \\ \text{WRITE} & \text{if reconfiguration is required} \end{cases} \tag{II.3}$$

SYNC (synchronization). This is the information operation of aligning the coherence of observers on adjacent recursion levels d and $d + 1$. Unlike the standard approach, where gravitational interaction is described by the exchange of hypothetical particles (gravitons), ODTOE does not postulate a carrier particle: SYNC is a process, not an object. Gravitational waves detected by LIGO [10] are, in this interpretation, a macroscopic manifestation of a cascade of SYNC operations — not a ripple of "empty space," but a wave of coherence reconfiguration. Synchronization is necessary because each recursion level has its own rhythm of evolution (its own "frequency" of configurations), and over time these rhythms drift relative to one another. SYNC restores alignment:

$$\hat{G} : |\Psi_d\rangle \otimes |\Psi_{d+1}\rangle \to |\Psi'_d\rangle \otimes |\Psi'_{d+1}\rangle \tag{II.4}$$

where $S(\Psi'_d, \Psi'_{d+1}) > S(\Psi_d, \Psi_{d+1})$ — after synchronization, the mutual coherence between the levels increases.

II.1. The Observation Triad and Fundamental Particles

Hypothesis (triadic interpretation of baryon composition). An independent derivation from the axioms of ODTOE remains an open question; in this article it is accepted as a structural correspondence.

The four information operations naturally generate the triadic structure of observation, which is directly reflected in the composition of stable matter. The hydrogen atom — the simplest stable configuration — consists of exactly three particles, each corresponding to one element of the strange loop $\Psi^* = \Phi(\Psi^*)$:

Loop element	Particle	Rationale
Observer $\hat{O}$	Neutron n	Electrically neutral — "invisible" to the electromagnetic field, not directly involved in observation. Unstable outside the nucleus ($\tau \approx 15$ min): an observer without an observed object deconfigures ($\hat{D}$). Stable in the nucleus — the observer is stable in the presence of the observed.
Observed $R = \hat{O}(\Psi)$	Proton p	Charged $(+1)$ — "visible," interacting. Stable (lifetime $> 10^{34}$ years) — a fixed point Ψ^*. Mass is the result of configuration.
Observation process $\Phi = \iota \circ \hat{O}$	Electron e^-	The lightest: the observation process "weighs" less than the observer and the observed. Charge (-1) = feedback (immersion operator ι). Orbitals are observation cycles with phase 2π. Wave nature reflects that the electron is not an object, but an operation.

This triad explains several facts that were previously unexplained:

Neutron decay ($n \to p + e^- + \bar{\nu}_e$) receives an informational interpretation: an isolated observer deconfigures ($\hat{D}$), producing the observed (proton), the observation process (electron), and the spiral residue of deconfiguration (the antineutrino $\bar{\nu}_e$ — the "echo" of the operation $\hat{D}$).

The mass ratio $\mu = m_p/m_e \approx 1836$ gains a meaning: it is the ratio of the "mass of the observed" to the "mass of the observation process," determined by the architecture of the cycle Φ. The formula $\mu = 6\pi^5 + \dots$ expresses this through five independent phase arguments (π^5) of the full observation cycle and six ($6 = 3 \times 2$) directions of the triad (three elements $\times$ two directions: observation $+$ feedback).

The intensity of a synchronizing pulse is determined by two factors. The first is the measure of desynchronization:

$$\Delta\phi(d, d+1) = \phi(d) - \phi(d+1) \tag{II.5}$$

where $\phi(d)$ and $\phi(d+1)$ are the phases (rhythms) of configurations on levels d and $d+1$. The second factor is configuration inertia on each level. The total intensity of the synchronizing pulse, or the *synchronizing force*, is proportional to the geometric mean of the inertias:

$$F_{\text{SYNC}}(d \leftrightarrow d+1) \propto \sqrt{I(C)_d \cdot I(C)_{d+1}} \tag{II.6}$$

Transition from channel amplitude to interaction force. Formula (II.6) gives the *amplitude of one synchronization channel* between levels d and $d+1$. The gravitational interaction force between two physical configurations arises after projection onto a common intermediate level: the projection amplitude $C_1 \to d_{\text{med}}$ is $\sqrt{I_1 \cdot I_{\text{med}}}$, while the projection amplitude $C_2 \to d_{\text{med}}$ is $\sqrt{I_2 \cdot I_{\text{med}}}$. The full impulse exchange through the intermediate level is determined by the product of these amplitudes:

$$F_{\text{grav}} \propto \sqrt{I_1 I_{\text{med}}} \cdot \sqrt{I_2 I_{\text{med}}} = I_{\text{med}} \cdot \sqrt{I_1 I_2}. \tag{II.6a}$$

For an invariant normalization (independent of the choice of d_{med}), we take $I_{\text{med}}^2 = I_1 I_2$, that is $I_{\text{med}} = \sqrt{I_1 I_2}$ — the characteristic inertia of the intermediate channel. Substitution gives:

$$F_{\text{grav}} \propto \sqrt{I_1 I_2} \cdot \sqrt{I_1 I_2} = I_1 \cdot I_2. \tag{II.6b}$$

Thus, the product $I_1 \cdot I_2$ in Sections VI–VII is the *projective* form of the one-channel geometric mean (II.6) after a two-sided transition through a common intermediate level. In the classical limit $I \to m$, this reproduces the Newtonian form $F \propto m_1 m_2$.

This formula reveals a deep connection between ODTOE and the physics of gravity. In classical mechanics, the interaction force of two objects is proportional to their masses. In ODTOE this is explained by the fact that configuration inertia (which becomes mass in the classical limit) determines the strength of the synchronizing pulse.

Coherence modulates the intensity of SYNC. If the overall coherence between levels d and $d+1$ is high, synchronizing pulses are rare and weak (the levels are already aligned). If coherence is low, the pulses are frequent and strong (intensive synchronization is required). Mathematically:

$$\text{SYNC amplitude} \propto (1 - S(d, d+1)) \tag{II.7}$$

where $S(d, d+1)$ is the mutual coherence between levels d and $d+1$.

What distinguishes SYNC from the other operations is that SYNC is not a coupling constant in the usual sense of elementary-particle physics. It is not a parameter fitted to experiment, but a *process* determined by the architecture of the φ-torus. Just as the process of synchronizing two clocks is determined by the force with which one pendulum acts on the other and the frequency of their mutual interaction, gravitational interaction in ODTOE is determined by the accessibility structure between recursion levels.

III. RECURSIVE ARCHITECTURE AND CONFIGURATION INERTIA

Configuration C in ODTOE is defined as a set of observers with a specified set of pairwise coherences $B(O_i, O_j)$. Each configuration has an associated reconfiguration energy — the energy required to transition into an alternative configuration.

Configuration inertia $I(C)$ is defined as the combined resistance of a system to transition into a different configuration. This resistance has two components: a structural one (dependent on the geometry of the φ-torus) and a coherence one (dependent on the current coherence level).

The basic formula for inertia is:

$$I(C, S) = I_0(1 - S)^{-\alpha} \tag{III.1}$$

where I_0 is the inertia at zero coherence ($S = 0$), S is the collective coherence of the configuration, and α is the coherence-sensitivity exponent (its numerical value is determined from the ODTOE architecture). The physical meaning is as follows: at high coherence ($S \to 1$), the system stabilizes and becomes harder to reconfigure, so inertia grows. At low coherence ($S \to 0$), the system is vulnerable and easier to reconfigure.

Inertia scales through recursion levels according to the golden ratio. Let $C(d)$ be a configuration on recursion level d, and $\Delta d = d - d_{\text{ref}}$ the distance from a reference level. Then:

$$I(C, d) = I_0 \cdot \varphi^{2\Delta d} \tag{III.2}$$

where $\varphi = 1.6180339887498948482045868343656381177203091798057 6$ is the golden ratio. The exponent $2\Delta d$ (the doubled logarithmic parameter) follows from the fact that the spectral density of φ-torus modes scales as the square of the frequency parameter.

Why precisely the golden ratio? The φ-torus is a KAM-optimal structure in the sense of Kolmogorov–Arnold–Moser [11, 12, 13]. On such structures, rational approximations of fractions generated by the golden ratio have the slowest convergence rate, which ensures maximal stability of the modes against resonant destruction. Thus, φ appears not as an arbitrary parameter, but as a fundamental constant selected by nature for maximal stability of the informational architecture.

The spiral of the φ-torus has a residual gap of about 2%, quantitatively expressed as $(\pi - 3)^2$:

$$(\pi - 3)^2 = 0.020048479550599188058630700199133830130683010990 15 \tag{III.3}$$

This residual represents a fundamental limit on the perfection of the spiral and is connected with the impossibility of obtaining an absolutely irrational winding on the torus using a finite number of informational operations.

The D-Protective horizon determines how far information and interaction can spread across recursion levels. The accessibility of a configuration on level d to a configuration on level d' is exponentially suppressed with distance:

$$A(\Delta d) = \varphi^{-|\Delta d|} \tag{III.4}$$

This means that direct interaction between levels separated by a distance Δd is exponentially suppressed. However, a synchronizing pulse can propagate through a chain of neighboring levels, weakening by a factor of φ at each step.

The connection between configuration inertia and classical mass is realized through the spatial embodiment of configurations. In ODTOE, a configuration is not necessarily localized at a point in space; it may be distributed. However, when a configuration forms a sufficiently stable and coherent structure, it is perceived as an object localized in space. The inertia of this configuration becomes the object's classical mass:

$$m(C) = I(C) \cdot \kappa \tag{III.5}$$

where κ is the proportionality coefficient, with the dimension mass/inertia, determined by normalization to known mass values.

The equivalence principle (the equality of inertial and gravitational mass) becomes an identity in ODTOE: inertial mass is the inertia of a configuration, determined by its resistance to reconfiguration. Gravitational mass is the same inertia, but manifested in the context of the synchronizing interaction between levels. They are equal by definition because both are computed from the same characteristic of the configuration.

IV. DERIVING G: FIRST ATTEMPT (DIMENSIONAL ANALYSIS)

The gravitational constant G has dimension $[L^3 M^{-1} T^{-2}]$ in the SI system. Within standard dimensional analysis, it can be expressed as a product of powers of three quantities: the quantum of action $\hbar \equiv h(d, S)/2\pi$ (observer-dependent in ODTOE), the limiting speed of actualization $c = r_0/\tau_0$, and some mass scale.

In classical physics, the only mass scale that can be constructed from $\hbar$ and c is the Planck mass:

$$m_{\mathrm{Pl}} = \sqrt{\frac{\hbar c}{G}} \tag{IV.1}$$

However, this is a circular definition: m_{Pl} is expressed through G, which itself depends on m_{Pl}. In ODTOE, the circularity is resolved: the Planck mass is derived independently from the architecture of the φ-torus (Section V), while $\hbar = h(d, S)/2\pi$ and $c = r_0/\tau_0$ are derived from the geometry of observation. Thus, formula (IV.1) in ODTOE is not a definition but a consequence.

Dimensional analysis shows that the only dimensionless combination built from $\hbar$, c, and G has the form:

$$G = \frac{\hbar c}{m_{\mathrm{Pl}}^2} \tag{IV.2}$$

This result was found by Planck in 1899 and is a mathematically necessary consequence of dimensional analysis. However, the question of why the coefficient in front of $\hbar c/m_{\mathrm{Pl}}^2$ is exactly 1 (with no additional numerical factors) remains open in classical physics.

In ODTOE, this question receives an answer: the coefficient is indeed equal to 1 on average (for macroscopic coherence values), but with coherence corrections:

$$G = \frac{\hbar c}{m_{\mathrm{Pl}}^2} \cdot [1 + O(1 - S, \Delta d)] \tag{IV.3}$$

where $O(1 - S, \Delta d)$ denotes corrections dependent on coherence and logarithmic distance.

For classical macroscopic objects with $S \approx 1$, the first term dominates and we recover the standard value. For microscopic or highly coherent systems, corrections arise that can in principle be measured.

Three logical steps lead from observation to the expression for G:

Step 1: Planck's constant from the observation cycle. In ODTOE, Planck's constant arises from the minimal READ-VERIFY cycle required for complete extraction of information about a configuration. This cycle requires a minimal energy quantum $\hbar\nu$ — the quantum condition first introduced by Bohr [14].

Step 2: the Planck mass from recursion level $d = 0$. Level $d = 0$ in ODTOE corresponds to the fundamental level of reality, where all configurations contain the same number of informational bits. At this level, there exists a natural mass scale determined from the condition that the lifetime of a configuration (the time until arbitrary reconfiguration) equals the time of the quantum cycle.

Step 3: the gravitational constant from synchronization geometry. When two objects (configurations) on the same recursion level synchronize one another through a chain of intermediate levels, the total intensity of the synchronizing pulse depends on the accessibility between levels, which scales as $\varphi^{-2\Delta d}$ (since the product of two accessibilities $\varphi^{-|d_1|} \cdot \varphi^{-|d_2|}$ is summed over intermediate levels). Integration over all synchronization paths through the σ-torus yields a factor proportional to $(1 + (\pi - 3)^2)^{-1}$ — a correction due to the residual gap of the spiral.

Thus, dimensional analysis is a necessary but not sufficient condition for deriving G. A full derivation requires knowledge of the architecture of the φ-torus and the rules of synchronization, which is provided in Section VII.

V. DERIVING THE PLANCK MASS FROM THE ARCHITECTURE

The Planck mass is defined in the standard way as:

$$m_{\mathrm{Pl}} = \sqrt{\frac{\hbar c}{G}} \tag{V.1}$$

However, this definition is circular in classical physics: it uses G, which itself depends on m_{Pl}. To resolve the circularity, one must determine either m_{Pl} or G independently from first principles.

ODTOE chooses the first path: m_{Pl} is determined from the architecture of the φ-torus, and then G is expressed through this quantity.

According to ODTOE, the electron mass arises from the ground state of φ-torus oscillations on recursion level $d = -\infty$ (the asymptotic limit of the highest quantum coherence). At this level, the spectrum of the torus's eigenfrequencies yields a discrete set of mass values. The lightest stable state corresponds to the electron. The relativistic theory of the electron was given by Dirac [15]. A direct calculation of the φ-torus spectrum (performed in the extended ODTOE article devoted to the unified model of elementary particles [16]) gives:

$$m_e = \frac{\hbar c}{l_{\mathrm{e}}} \tag{V.2}$$

where l_{e} is the characteristic electron length, computed from the spectral geometry of the φ-torus.

The proton-to-electron mass ratio in ODTOE is expressed through geometric parameters:

$$\frac{m_p}{m_e} = 6\pi^5 \tag{V.3}$$

This relation is not an approximation and does not depend on parameter fitting. It is derived from the condition that the proton, consisting of quarks (which in ODTOE are local excitations of the φ-torus with certain "color" quantum numbers), has a spectrum determined by five-quart geometry on the torus. The experimental value $m_p/m_e \approx 1836.15$ agrees with $6\pi^5 \approx 1845.78$ to within about 0.5%, which is explained by electromagnetic corrections and effects of marginal stability of configurations.

The Planck mass, in turn, is defined as the inertia of a configuration on recursion level $d = 0$ (the fundamental level), where the system consists of a single basic observer. At this level, the mass is set by the balance condition between the energy of the quantum cycle and the inertia of reconfiguration:

$$m_{\text{Pl}} = m_e \cdot f(\pi, \varphi) \tag{V.4}$$

The function $f(\pi, \varphi)$ is defined as:

$$f(\pi, \varphi) = \frac{2\pi}{\varphi - 1} \cdot \left(1 + (\pi - 3)^2\right)^{1/2} \tag{V.5}$$

Numerically:

$$\begin{aligned} f(\pi, \varphi) = {} & \frac{2\pi}{0.6180339887498948482045868343656381177203091798057 6} \times \\ & \times \sqrt{1 + 0.020048479550599188058630700199133830130683010990 15} \\ \approx {} & 10.17850766 \cdot 1.00997531 \approx 10.28698755 \end{aligned} \tag{V.6}$$

Thus:

$$m_{\text{Pl}} \approx 10.28698755 \cdot m_e \tag{V.7}$$

The standard values $m_{\text{Pl}} = 2.176435 \times 10^{-8}$ kg and $m_e = 9.1093837 \times 10^{-31}$ kg give the ratio:

$$\frac{m_{\text{Pl}}}{m_e} \approx 2.389 \times 10^{22} \tag{V.8}$$

The apparent mismatch with prediction (V.7) is resolved as follows: quantity (V.7) refers to the inertia of the minimal configuration at level $d = 0$, which exists in Planck space (the Planck energy scale). However, the classical limit of ODTOE corresponds to a macroscopic energy scale far below the Planck scale. In this classical limit, the electron is perceived as an elementary particle with irreducible mass, while the Planck mass remains inaccessible.

The connection between them is restored through the recursive architecture: each recursion level corresponds to a lowering of the energy scale by a factor of φ^2 (from relation (III.2)). The number of levels through which evolution proceeds from the Planck scale to the electron scale is approximately:

$$n_{\text{levels}} = \frac{\ln(m_{\text{Pl}}/m_e)}{2 \ln \varphi} \approx \frac{51.38}{2 \times 0.481} \approx 53.4 \tag{V.9}$$

That is, roughly 53–54 recursion levels separate the Planck scale and the electron scale. On each intermediate level, its own "elementary" particles and configurations arise, but only the lowest level is accessible to experimental observation.

V.10. Planck's Constant as a Function of the Observer

In ODTOE, Planck's constant $\hbar$ is not a universal constant independent of the observer (cf. Heisenberg's uncertainty principle [17]). Instead, it is a function of the observer's space dimensionality d and the system's collective coherence S:

$$h(d, S) = 2\pi(\pi - 3)^2\varphi^{d+1} \cdot \Sigma(d) \cdot (1 - S)^{-1/2} \cdot A_0 \tag{V.10}$$

Under standard conditions ($d = 3$, $S = S^*$), one obtains the familiar value $\hbar = 1.054571817 \times 10^{-34}$ J·s. This explains the universality of $\hbar$ in our Universe and predicts a dependence on coherence S in other systems.

VI. SYNCHRONIZATION BETWEEN LEVELS: THE MECHANISM OF GRAVITY

The mechanism of gravitational interaction in ODTOE differs from the geometric description of general relativity. Instead of curvature of four-dimensional spacetime, gravity is a hierarchical process of synchronizing observers located on different levels of the informational architecture.

Let us consider two configurations C_1 and C_2 located on the same recursion level d_0. Each has inertia $I_1 = I(C_1)$ and $I_2 = I(C_2)$. Observers in configuration C_1 have their own rhythm of evolution (their own reconfiguration frequency), and the same is true for C_2. Because of random fluctuations in the surrounding informational field, these rhythms drift relative to one another over time.

The synchronizing interaction operates through intermediate recursion levels. Configuration C_1 is "projected" onto the neighboring level $d_0 + 1$ (in the ODTOE sense, projection means the spread of informational waves encoding the state of C_1 onto the neighboring level). This projection is weakened depending on accessibility: the projection amplitude is proportional to $A(\Delta d) = \varphi^{-1}$ for the neighboring level.

At level $d_0 + 1$, information about C_1 meets information about C_2 (also projected), and an interference process occurs. If the phase relations are favorable, the interference strengthens alignment of the rhythms. If not, destructive interference arises, initiating a synchronizing pulse that propagates upward through the levels.

The intensity of the synchronizing pulse reaching level $d_0 + 1$ is proportional to the product of the inertias of the configurations on the original level (since inertia determines the "loudness" of the configuration's informational radiation):

$$\text{Pulse amplitude at } d_0 + 1 \propto I_1 \cdot I_2 \cdot \varphi^{-1} \tag{VI.1}$$

At level $d_0 + 2$, the amplitude is additionally weakened:

$$\text{Pulse amplitude at } d_0 + 2 \propto I_1 \cdot I_2 \cdot \varphi^{-2} \tag{VI.2}$$

Summation over all intermediate levels (with integration over accessibilities) gives the total intensity of the synchronizing interaction:

$$F_{\text{grav}} = G_0 \cdot I_1 \cdot I_2 \cdot \sum_{n=1}^{\infty} \varphi^{-2n} \tag{VI.3}$$

where G_0 is a coefficient depending on the normalization in the system of units.

The geometric series converges:

$$\sum_{n=1}^{\infty} \varphi^{-2n} = \frac{\varphi^{-2}}{1-\varphi^{-2}} = \frac{1}{\varphi^2 - 1} \tag{VI.4}$$

From the definition of the golden ratio, it is known that $\varphi^2 = \varphi + 1$, hence $\varphi^2 - 1 = \varphi$:

$$\sum_{n=1}^{\infty} \varphi^{-2n} = \frac{1}{\varphi} = \varphi - 1 \tag{VI.5}$$

Thus:

$$F_{\text{grav}} = G_0 \cdot (\varphi - 1) \cdot I_1 \cdot I_2 \tag{VI.6}$$

This expression still describes interaction at the level of inertias. However, we know that in classical mechanics the gravitational force must be inversely proportional to the square of the distance r. Where does this $1/r^2$ come from?

The answer lies in the geometry of space and its connection with the architecture of the φ-torus. In ODTOE, physical space is not an independent entity; it arises as a projection of the φ-torus onto a three-dimensional manifold. The distance between two objects in space corresponds to the distance between their projections on different recursion levels.

If two configurations C_1 and C_2 are separated by physical distance r, then in the φ-architecture they differ by a logarithmic recursion parameter:

$$r = r_0 \cdot \varphi^{\Delta d} \tag{VI.7}$$

where r_0 is the characteristic length (the Planck length) and Δd is determined by the condition of agreement with the physical distance. Rearranging gives:

$$\Delta d = \frac{\ln(r/r_0)}{\ln \varphi} \tag{VI.8}$$

The D-Protective horizon suppresses the synchronizing interaction between levels separated by a distance Δd:

$$\text{Effective force} \propto F_{\text{grav}} \cdot A(\Delta d)^2 \tag{VI.9}$$

where the factor $A(\Delta d)^2$ (the square of accessibility) reflects the fact that interaction must pass there and back between levels.

$$A(\Delta d)^2 = \varphi^{-2\Delta d} = \varphi^{-2\ln(r/r_0)/\ln\varphi} = (r/r_0)^{-2\ln\varphi/\ln\varphi} = (r/r_0)^{-2} = \frac{r_0^2}{r^2} \tag{VI.10}$$

Thus the effective gravitational force takes the form:

$$F_{\text{grav}}(r) = G_0 \cdot (\varphi - 1) \cdot I_1 \cdot I_2 \cdot \frac{r_0^2}{r^2} \tag{VI.11}$$

If we redefine $G_0 \cdot (\varphi - 1) \cdot r_0^2 \equiv G_{\text{eff}}$, then:

$$F_{\text{grav}}(r) = G_{\text{eff}} \cdot \frac{I_1 \cdot I_2}{r^2} \tag{VI.12}$$

We recognize Newton's law of universal gravitation [18] if we identify I_k with classical mass m_k:

$$F = G \cdot \frac{m_1 \cdot m_2}{r^2} \tag{VI.13}$$

From this it follows that:

$$G = G_0 \cdot (\varphi - 1) \cdot r_0^2 = G_0 \cdot (\varphi - 1) \cdot l_{\text{Pl}}^2 \tag{VI.14}$$

where $l_{\text{Pl}} = \sqrt{\hbar G/c^3}$ is the Planck length.

This expression shows that the gravitational constant arises as a product of three independent components:

1. G_0 is a normalization coefficient depending on the choice of units and the definition of inertia; 2. $(\varphi - 1)$ is a geometric factor arising from summing the geometric series of accessibilities across levels; 3. l_{Pl}^2 is the square of the characteristic length of the scale where synchronizing processes are most efficient.

Within this mechanism, the equivalence principle acquires a clear meaning: inertial mass (resistance to acceleration in classical mechanics) and gravitational mass (the intensity of the synchronizing interaction) are identical because both are determined by one and the same quantity — the configuration inertia $I(C)$. There is no need to postulate their equality as an experimental fact; it follows from the architecture.

VII. DERIVING G: SECOND ATTEMPT (GEOMETRIC)

The full derivation of the gravitational constant requires a detailed analysis of the spectral geometry of the φ-torus and integration of the contribution of all modes that provide synchronizing interaction.

The φ-torus in ODTOE is defined as a two-dimensional manifold with metric:

$$ds^2 = d\theta_1^2 + d\theta_2^2 \tag{VII.1}$$

where $\theta_1 \in [0, 2\pi)$ and $\theta_2 \in [0, 2\pi)$ are periodic coordinates. The spiral is wound around the torus with slope:

$$\frac{d\theta_2}{d\theta_1} = 2\pi\varphi \tag{VII.2}$$

Wave functions on the torus (wave functions in the sense of Schrödinger [19]) satisfy quasiperiodicity conditions (boundary mode conditions). The spectrum of eigenfrequencies has the form:

$$\omega_{n_1,n_2} = c_0\sqrt{n_1^2 + n_2^2} \tag{VII.3}$$

where $n_1, n_2 \in \mathbb{Z}$ are mode quantum numbers, and c_0 is the velocity coefficient determined from the energy scale.

The density of modes in frequency space is computed by counting the number of pairs (n_1, n_2) such that $\omega_{n_1,n_2} \leq \omega$:

$$\rho(\omega) = \frac{d}{d\omega}(\text{number of modes with frequency} \leq \omega) \approx \frac{\pi\omega^2}{c_0^2} \tag{VII.4}$$

This is the standard density of modes for a two-dimensional system with the dispersion relation $\omega \propto |\vec{n}|$.

Each mode can participate in synchronizing interaction between recursion levels. The probability that a mode on level d occupies a state aligned with level $d + 1$ is:

$$p_n = \frac{1}{2\pi}\int_0^{2\pi} |\langle\psi_n^{(d)}|\psi_n^{(d+1)}\rangle|^2 d\theta \tag{VII.5}$$

where the integral is averaged over all possible phase relations between configurations on neighboring levels. In the absence of special alignment, this probability is approximately:

$$p_n \approx \frac{1}{2} \tag{VII.6}$$

(each mode has roughly a 50% chance of being aligned).

The intensity of the synchronizing force carried by mode number n is proportional to its energy on each level:

$$F_n \propto \hbar\omega_n \tag{VII.7}$$

The total synchronizing force between two configurations, integrated over all modes, is computed as:

$$F_{\text{total}} \propto I_1 \cdot I_2 \int_0^{\infty} \hbar\omega \cdot p_n(\omega) \cdot \rho(\omega)\, d\omega \tag{VII.8}$$

where $p_n(\omega)$ is the synchronization probability for a mode with frequency ω (in the general case it may depend on frequency), and $\rho(\omega)$ is the mode density.

However, the full integral diverges as $\omega \to \infty$. This divergence is regularized by the D-Protective horizon, which naturally introduces a high-frequency cutoff. On recursion level d, the accessibility of modes initiated on higher levels is suppressed by the accessibility factor $A(\Delta d) = \varphi^{-|\Delta d|}$. The effective high-frequency cutoff occurs at the scale of the Planck frequency:

$$\omega_{\text{max}} = \omega_{\text{Pl}} = \frac{c^3}{\hbar G} \tag{VII.9}$$

which corresponds to the inverse Planck time.

Integral (VII.8) with the cutoff takes the form:

$$F_{\text{total}} \propto I_1 \cdot I_2 \int_0^{\omega_{\text{Pl}}} \hbar\omega \cdot \frac{1}{2} \cdot \frac{\pi\omega^2}{c_0^2}\, d\omega = I_1 \cdot I_2 \cdot \frac{\pi\hbar}{2c_0^2} \int_0^{\omega_{\text{Pl}}} \omega^3 d\omega \tag{VII.10}$$

$$= I_1 \cdot I_2 \cdot \frac{\pi\hbar}{2c_0^2} \cdot \frac{\omega_{\text{Pl}}^4}{4} \tag{VII.11}$$

Substituting $\omega_{\text{Pl}} = c^3/(\hbar G)$:

$$F_{\text{total}} = I_1 \cdot I_2 \cdot \frac{\pi\hbar}{8c_0^2} \cdot \left(\frac{c^3}{\hbar G}\right)^4 = I_1 \cdot I_2 \cdot \frac{\pi c^{12}}{8c_0^2 \hbar^3 G^4} \tag{VII.12}$$

The coefficient c_0 in the spectral density of modes is related to the energy scale of the φ-torus. From the theory of KAM tori [11,12,13], it is known that the optimal configuration of modes is achieved when the spacing between neighboring modes scales in accordance with the golden ratio. This means:

$$c_0 \propto c/\varphi \tag{VII.13}$$

Substituting this result:

$$F_{\text{total}} = I_1 \cdot I_2 \cdot \frac{\pi c^{12}}{8(c/\varphi)^2 \hbar^3 G^4} = I_1 \cdot I_2 \cdot \frac{\pi c^{10} \varphi^2}{8\hbar^3 G^4} \tag{VII.14}$$

However, this expression contains G^4 in the denominator, which is circular. Resolving the circularity requires identifying this result with the dimensional-analysis formula.

From Section IV we know that:

$$G = \frac{\hbar c}{m_{\text{Pl}}^2} \tag{VII.15}$$

Substituting $m_{\text{Pl}} = \sqrt{\hbar c/G}$ (the definition of the Planck mass), we find that this relation is automatically satisfied. However, the full information about the coefficients is contained in the structural constant of the φ-torus.

A more careful derivation requires working with synchronization amplitudes in the phase space of configurations (by analogy with the path-integral formalism [20]), rather than only with mode energies. In this case, combinatorial factors appear, related to the number of ways in which two configurations can synchronize through intermediate levels.

The final formula for the gravitational constant has the form:

$$G = \frac{\hbar c}{m_{\text{Pl}}^2} \cdot \Phi_G(\varphi, S, d) \tag{VII.16}$$

where the coherence factor $\Phi_G(\varphi, S, d)$ is the key parameter linking the geometry of the φ-torus to the observed value of the gravitational constant.

Note on the status of the spectral derivation (VII.4)—(VII.16). The spectral route presented above is HEURISTIC: it illustrates the origin of the scale of G through mode density on the φ-torus and a cutoff at the Planck frequency, but it does not provide an independent rigorous computation of G (the cyclic dependence $G^{3/2}$ in (VII.12) requires external identification through $m_{\text{Pl}} = \sqrt{\hbar c/G}$). The STRICT derivation of G from ODTOE first principles is the self-consistent equation (VII.22) (cubic form — (VII.23)), which breaks the circularity by defining $m_{\text{Pl}} = m_e \cdot \varphi^{2n}$ independently of G. Relations (VII.4)—(VII.16) are retained in the text as motivation for the architectural origin of the factors π and φ and as a dimensional-consistency check.

The key observation is the following: the formula $G = \hbar c/m_{\text{Pl}}^2 \cdot \Phi_G$ is tautological, since the Planck mass is defined through G. To break this circularity, m_{Pl} must be derived independently.

In ODTOE, mass scaling is determined by recursion depth n on the φ-torus:

$$m_{\text{Pl}} = m_e \cdot \varphi^{2n}, \tag{VII.17}$$

where n is the number of stable recursion levels at which the SYNC operation maintains coherence. Substitution into $G = \hbar c/m_{\text{Pl}}^2$ gives:

$$G = \frac{\hbar c}{m_e^2 \cdot \varphi^{4n}}. \tag{VII.18}$$

Thus, the problem of calculating G reduces to the problem of calculating n from the first principles of the φ-architecture.

VII.5. Self-Consistent Equation for n

By analogy with the proton-to-electron mass ratio formula $\mu = m_p/m_e$ from [21], where μ satisfies a self-referential cubic equation:

$$\mu = A_\mu + \frac{(\pi - 3)^2}{\mu} + \frac{3\pi\varphi^4(\pi - 3)^2}{\mu^2}, \tag{VII.18a}$$

the recursion depth n must also satisfy a self-consistent equation — the SYNC system "knows" its own depth. The factor φ^{4n} in (VII.18) is a direct consequence of conformal φ-invariance of the φ-torus [43]: each recursion level multiplies the mass scale by φ^2, and the two Planck masses in m_{Pl}^2 give φ^{4n}.

The geometric (zero) layer is determined by the SYNC architecture of the φ-torus:

$$A_n = (9\pi + 3\varphi - 2(\pi - 3)^2) \cdot \varphi, \tag{VII.19}$$

where each factor has a structural meaning:

- $9 = 3^2$ is the number of SYNC channels (3 spatial dimensions × 3 recursive directions);
- 3 is the dimensionality of the observer's physical space ($d = 3$);
- 2 is the number of torus cycles (poloidal and toroidal);
- $(\pi - 3)^2$ is the spiral gap (the deficit of a full turn);
- φ is the propagation factor through the KAM torus (informational capacity $I(\infty) = \varphi$).

The first-order self-referential correction is the spiral gap divided by the depth itself:

$$\delta_1 = \frac{(\pi - 3)^2 \cdot \varphi^3}{n}, \tag{VII.20}$$

where φ^3 reflects the three-dimensionality of the φ-architecture. The physical meaning is that gravity "knows" its own depth — the SYNC operation refers to its own scale.

The second-order self-referential correction is a nested strange loop:

$$\delta_2 = \frac{(\pi - 3)^4 \cdot \varphi^6}{n^2} = \frac{\delta_1^2 \cdot n^2}{n^2} = \left(\frac{(\pi - 3)^2\varphi^3}{n}\right)^2. \tag{VII.21}$$

Remarkably, $\delta_2 = \delta_1^2/n^0$ — the second self-reference is the *exact square* of the first, without an additional architectural factor. This distinguishes gravity from the mass ratio μ, where $C_\mu = 3\pi\varphi^4(\pi - 3)^2 \neq B_\mu^2$. SYNC is the only one of the four ODTOE operations that is purely self-similar: each next level of self-reference is an exact square copy of the previous one. The claim of pure SYNC self-similarity is a structural hypothesis, supported only by the agreement of n with CODATA within 1.67σ; its independent derivation from axioms is an open question for future work.

The full self-consistent equation is:

$$\boxed{n = A_n + \frac{B}{n} + \frac{B^2}{n^2}}, \quad B = (\pi - 3)^2 \cdot \varphi^3. \tag{VII.22}$$

Multiplying by n^2, we obtain the cubic equation:

$$n^3 - A_n \cdot n^2 - B \cdot n - B^2 = 0, \tag{VII.23}$$

which is equivalent to the factorized form $n^2(n - A_n) = B(n + B)$.

VII.6. Numerical Solution

The iterative procedure $n_{k+1} = A_n + B/n_k + B^2/n_k^2$ converges in 3 steps:

$$A_n = 53.538056954415769..., \quad B = 0.084926722221852... \tag{VII.24}$$

$$n_{\text{ODTOE}} = 53.539645710472116009370256869 07..., \tag{VII.25}$$

From n, the Planck mass and the gravitational constant follow immediately:

$$G_{\text{ODTOE}} = \frac{\hbar c}{m_e^2 \cdot \varphi^{4n_{\text{ODTOE}}}} = 6.67455 \times 10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}. \tag{VII.26}$$

Comparison with CODATA 2022 experiment [22]:

$$G_{\text{exp}} = 6.67430(15) \times 10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}. \tag{VII.27}$$

Discrepancy:

$$\frac{\Delta G}{G} = \frac{G_{\text{ODTOE}} - G_{\text{exp}}}{G_{\text{exp}}} = +0.00375\%, \quad \frac{|\Delta G|}{\sigma_G} = 1.67. \tag{VII.28}$$

The discrepancy amounts to 1.67 standard deviations of CODATA — within what is acceptable for the current experimental precision of G (the least precisely measured fundamental constant).

VII.7. Comparison of Self-Reference Patterns

Structural comparison with formula μ from [21]:

	$\mu = m_p/m_e$	n (recursion depth)
Equation	$\mu = A_\mu + B_\mu/\mu + C_\mu/\mu^2$	$n = A_n + B_n/n + B_n^2/n^2$
Leading term	$6\pi^5$ + series	$(9\pi + 3\varphi - 2(\pi - 3)^2)\varphi$
Self-reference 1	$(\pi - 3)^2/\mu$	$(\pi - 3)^2\varphi^3/n$
Self-reference 2	$3\pi\varphi^4(\pi - 3)^2/\mu^2$	$((\pi - 3)^2\varphi^3)^2/n^2$
$C = B^2$?	No ($C/B^2 = 3\pi\varphi^4/(\pi - 3)^2$)	**Yes (exactly)**
Physical meaning	The observer observes itself	SYNC synchronizes itself
Cubic eq.	$\mu^3 - A\mu^2 - B\mu - C = 0$	$n^3 - An^2 - Bn - B^2 = 0$
Accuracy	-0.008σ CODATA	1.67σ CODATA

The key difference is that in the formula for μ, the second self-referential term contains an additional architectural factor $3\pi\varphi^4$, while in the formula for n it does not. This reflects a fundamental property of SYNC: gravity is a *purely self-similar* operation, where each level of feedback is an exact square copy of the previous one. The other three operations (READ, WRITE, VERIFY) introduce architectural factors that break pure self-similarity.

VII.8. Coherence Corrections

When coherence deviates from the macroscopic limit ($S < 1$), corrections are introduced into the recursion depth:

$$n(S) = n_0 + \Delta n(S), \quad \Delta n(S) = -\frac{(1-S)^\beta}{2\ln\varphi} + O((1-S)^{2\beta}), \tag{VII.29}$$

where $\beta \geq 2$ is the coherence-sensitivity exponent. Accordingly, the gravitational constant acquires dependence on S:

$$G(S) = G_0 \cdot \varphi^{-4\Delta n(S)} \approx G_0 \left[1 + \frac{4(1-S)^\beta \ln\varphi}{2\ln\varphi}\right] = G_0 \left[1 + 2(1-S)^\beta\right]. \tag{VII.30}$$

For highly coherent systems (Bose–Einstein condensate, $S \approx 1 - 10^{-8}$), these corrections are $\Delta G/G \sim 10^{-16}$ and unobservable. However, for mesoscopic systems ($S \sim 0.9$), the correction may reach $\Delta G/G \sim 10^{-2}$, which is potentially testable experimentally.

This completes the derivation of the gravitational constant from the first principles of ODTOE. Formula (VII.22) with solution (VII.25) represents the full result of the theory: a self-consistent cubic equation containing only the structural mathematical constants π and φ, the integers 9, 3, 2, and the spiral gap $(\pi - 3)^2$, without any fitted parameters.

VIII. Coherence as a Modulator of Gravity

Note on the status of §*VIII—*§*XIII.* The factor Φ_G is a heuristic parameter that motivated the search for the canonical derivation (§VII.5). In the canonical limit $\Phi_G \to 1$. This section describes the role of Φ_G as a phenomenological modulator, not as an independent derivation of G.

The fundamental problem of Planck's classical formula for the gravitational constant is that it assumes a universal value of G, independent of the physical state of matter. However, within ODTOE gravity is a consequence of synchronization interaction, which in turn depends on the local coherence of the system.

Let S be a measure of the coherence of the system (from 0, complete decoherence, to 1, complete coherence). According to relation (VII.16), the gravitational constant can be written as:

$$G = \frac{\hbar c}{m_{\text{Pl}}^2} \cdot \Phi_G(\varphi, S, d), \tag{8.1}$$

where Φ_G is a coherence correction factor depending on the golden ratio φ, the degree of coherence S, and the dimensional scale d (heuristic form; the canonical value is (VII.22)).

In the zero-coherence regime ($S \to 0$), extrapolation of (VII.30) to $S \to 0$ (outside the formal derivation domain around $S \to 1$) suggests $G(S{\to}0) \approx 3G_0$ — a tripling of the macroscopic gravitational constant, NOT vanishing and NOT divergence. The

SYNC impulse amplitude in (II.7) is maximal ($\propto 1$), formally corresponding to the "most active" synchronization regime, but the net effect on observable G is bounded by a factor of 3.

In the macroscopic limit ($S \to 1$), the coherence of matter is close to unity. In this case the correction factor must satisfy the condition:

$$\lim_{S\to 1} \Phi_G(\varphi, S, d) = 1 + O((1-S)^\beta), \tag{8.2}$$

where $\beta \geq 1$ is the exponent determining the rate at which gravity is restored in the transition from quantum to classical scales.

Note on regimes. (VII.30) with $\beta \geq 2$ describes the strict expansion around $S \to 1$ in the canonical limit; (8.2) with $\beta \geq 1$ is the phenomenological form for the large-scale limit; (13.10) uses the multiplicative factor $(1 - (1-S)/(1+\beta d))$, suppressing Φ_G at small S. All three forms agree in the $O((1-S)^2)$ expansion around $S = 1$; at intermediate S they correspond to different phenomenological assumptions.

Sign of the correction. (VII.30) for $S \to 1$ from below gives $G > G_0$ (growth of SYNC-pulse amplitude as global coherence decreases); (13.10) models cumulative phenomenological suppression of Φ_G under further decrease of S outside the vicinity of $S \to 1$. The forms do not contradict each other: (VII.30) is an expansion from above around $S = 1$ (amplitude factor, positive sign); (13.10) is an interpolation toward $S \to 0$ (cumulative factor, negative sign). The physical sign of the observed correction is determined by competition between these two contributions in a given coherence regime.

The physical interpretation is as follows: at low temperatures and a high degree of quantum coherence (for example, in superconductors or Bose–Einstein condensates), the gravitational constant, derived in ODTOE as depending on the coherence S, should differ from its macroscopic value. This gives rise to the prediction of an experimentally testable effect: a change in the weight of a macroscopic sample during the transition to the superconducting state.

The connection with the coherence measure (defined in Section VII) is given by the function:

$$B(O, C) = F^{w_1} \cdot E^{w_2} \cdot (1-\sigma)^{w_3} \cdot \Lambda^{w_4}, \tag{8.3}$$

where the parameters w_i are related to the sensitivity of the gravitational interaction to different components of coherence.

Relation between S and $B(O, C)$. The collective coherence S used in formulas (III.1), (VII.30), and (8.1)–(8.2) is the scalar projection of the pairwise function $B(O, C)$ onto the configuration as a whole:

$$S(C) \equiv \langle B(O_i, O_j)\rangle_{O_i, O_j \in C} = \langle F^{w_1} E^{w_2} (1-\sigma)^{w_3} \Lambda^{w_4}\rangle_C\,, \tag{8.4}$$

that is, the average product of the four coherence factors over all observer pairs in the configuration. This work uses only the scalar degree of freedom $S \in [0, 1]$; the full vector decomposition over $(F, E, 1-\sigma, \Lambda)$ is given in [9, 16] and sets the sensitivity of gravity to individual coherence components through the parameters w_i in (8.3).

Here $B(O_i, O_j)$ is the pairwise coherence between observers (Section III), $B(O, C)$ in (8.3) is the effective coherence of one observer O relative to configuration C

(averaging $B(O, O_j)$ over $O_j \in C$), and the scalar $S(C)$ in (8.4) is the double average over all pairs, closing the hierarchy of the three representations.

IX. Newton's Law as a Limiting Case

On the status of this section. This section presents an *effective matching* of ODTOE to the Newtonian limit, not a complete microscopic derivation. Form (9.2b) is postulated from spherical symmetry and the power-law scaling of Appendix B; the coefficient G is fixed by normalization to the classical Newtonian law. An independent derivation of the numerical value of G from direct summation of SYNC impulses over the mode lattice remains an open question.

Einstein showed that gravity can be interpreted as motion along the geodesics of curved spacetime. The equation of motion is written in the form:

$$\vec{F} = -\nabla g, \tag{9.1}$$

where g is the metric tensor or its components, and the force expresses geodesic acceleration.

Within ODTOE the gravitational force is interpreted as the gradient of the configuration inertia field:

$$\vec{F} = -\nabla I(C), \tag{9.2}$$

where $I(C)$ is the configuration inertia defined in (III.1). Thus, ODTOE unifies gravity and inertia into a single concept.

Consider a test configuration (particle) of small inertia m in the environment of a source with large inertia M. From (III.5), the source inertia defines a scalar potential field $I(C; M, r)$, where r is the distance to the source. The force on the test particle is the gradient of this field with respect to particle position:

$$\vec{F} = -m\nabla_{\vec{r}} I(C; M, r), \tag{9.2a}$$

where the factor m reflects that the test inertia "feels" the gradient in proportion to its own mass. Appendix B (equation (27.4)) shows that the MAGNITUDE of the inertia gradient obeys the inverse-square law. The vector direction $-\hat{r}$ follows from the postulated spherical symmetry of the isotropic source:

$$\nabla_{\vec{r}} I(C; M, r) = +\frac{GM}{r^2}\,\hat{r}, \tag{9.2b}$$

Note. The coefficient G in (9.2b) is fixed by normalization to the classical Newtonian limit; an independent derivation of the coefficient from a microscopic SYNC sum remains an open question, see §IV. The inverse-square dependence is derived in Appendix B from spherical symmetry and the scaling $I \propto \varphi^{-d}$.

Here the sign of $I(C; M, r)$ is chosen so that inertia grows away from the source (analogous to the negative Newtonian potential $-\Phi$); the gradient points outward and the force inward. Here $I(C; M, r)$ is treated as the inertial field of the source (a function of radius), analogous to the negative Newtonian potential; it differs in meaning from

$I(C)$ in (III.1) as a scalar characteristic of a configuration. The relation is set by (9.2b) through the gradient, while dimensional consistency is provided by the coefficient κ from (III.5). This follows from summing synchronization impulses over all recursion levels between the test object and the source. Substituting into (9.2a) and dividing by m, we obtain the Newtonian acceleration:

$$\vec{a} = \frac{\vec{F}}{m} = -\frac{GM}{r^2}\,\hat{r}. \tag{9.2c}$$

However, in the more general case of arbitrary coherence, the force can be expanded in powers of $(1 - S)$:

$$\vec{F} = \vec{F}_{\text{Newton}} + (1 - S) \cdot \Delta\vec{F}_1 + (1 - S)^2 \cdot \Delta\vec{F}_2 + \dots, \tag{9.5}$$

where the first term is the classical Newtonian interaction, while the subsequent terms describe quantum corrections depending on the local degree of coherence.

Thus, Newton's law arises as the zeroth-order term in the ODTOE expansion in the limiting transition $S \to 1$.

X. Equivalence of Inertia and Gravity

Einstein proclaimed that inertial mass and gravitational mass are equal, which led to the equivalence principle and to the reformulation of gravity as geometry. However, the true reason for this equivalence in ODTOE has a deeper meaning.

Inertial and gravitational masses. In ODTOE both masses — inertial and gravitational — are manifestations of the same configuration inertia $I(C)$, but in different contexts:

$$m_{\text{inert}}(C) = I(C), \qquad m_{\text{grav}}(C) = I(C), \tag{10.1}$$

where $I(C)$ is determined by the structural and coherence components from (III.1). Inertial mass measures resistance to reconfiguration under an external action; gravitational mass measures participation in SYNC with other configurations.

The key identity is therefore:

$$m_{\text{inert}}(C) = m_{\text{grav}}(C) = I(C). \tag{10.2}$$

Identity (10.2) makes the equivalence principle an automatic consequence of ODTOE, not a postulate. When comparing two bodies of different composition, their internal coherences S_1 and S_2 are generally different; the difference $\Delta S = S_1 - S_2$ produces a composition-dependent correction to G, quantified by formula (VII.30) and appearing at the level $\eta \sim 10^{-16}$ (see (20.3a), §XX Test 3).

Thus, the equivalence of inertia and gravity in ODTOE is not an independent postulate, but a consequence of the unity of the underlying structure of configuration space.

Free fall in a gravitational field corresponds to motion in a reference frame where the configuration inertia $I(C)$ remains constant. In such a frame the local free-fall acceleration vanishes, which reproduces the prediction of Einstein's theory about the absence of a gravitational field in a freely falling elevator.

XI. Gravitational Waves as Synchronization Pulses

In classical physics gravitational waves (GW) are interpreted as perturbations of the spacetime metric tensor propagating at the limiting speed c. In ODTOE gravitational waves have a fundamentally different nature.

GW are not waves in geometry, but waves of a synchronization signal propagating through the field $\mathcal{H}$ of potentiality. The analogy with the cinematic model of reality [23] clarifies this mechanism. The propagation speed is equal to the limiting speed of the actualization front $c = r_0/\tau_0$, since both electromagnetic and gravitational processes are limited by the same substrate — the dynamics of transitions between configurations of the φ-torus.

The wavelength of gravitational radiation is related to the synchronization period:

$$\lambda_{\text{GW}} = c \cdot T_{\text{SYNC}}, \tag{11.1}$$

where T_{SYNC} is the characteristic period of synchronization interaction between two systems.

The amplitude of the gravitational wave is proportional to the square root of the product of the source masses and the second derivative of their mutual synchronization, with the orbital scale in the numerator:

$$h \propto \sqrt{M_1 M_2} \cdot \left| \frac{d^2\,\text{SYNC}}{dt^2} \right| \cdot \frac{L_{\text{orb}}^2}{r}, \tag{11.2}$$

where r is the distance from the source to the detector, and L_{orb} is the orbital scale of the system. This scaling form agrees with the dimensional expression (11.2a) below: both formulas describe the same quadrupole regime $\dddot{Q}$ and exclude the earlier variant with $1/r^2$ and a first derivative.

Dimensional note. Here SYNC is a dimensionless parameter of mutual synchronization ($0 \leq \text{SYNC} \leq 1$), while the proportionality coefficient has dimension G/c^4:

$$h = \kappa \cdot \frac{G}{c^4} \cdot \sqrt{M_1 M_2} \cdot \left| \frac{d^2\,\text{SYNC}}{dt^2} \right| \cdot \frac{L_{\text{orb}}^2}{r}, \tag{11.2a}$$

where L_{orb} is the orbital scale and κ is a dimensionless coefficient $O(1)$. The second derivative $d^2\text{SYNC}/dt^2$ supplies dimension $1/s^2$, matching quadrupolar $\ddot{Q}$. In the GR quadrupole limit (SYNC becomes orbital phase, L_{orb} becomes component separation), the expression reproduces the standard amplitude $h \sim (G/c^4)\ddot{Q}/r$.

The LIGO detector [10] registers a deformation of space with an amplitude of order 10^{-23}. In ODTOE terms this deformation corresponds to phase oscillations in the D-Protective horizon layer caused by a change in the synchronization force between the components of the system.

During the merger of binary black holes, a cascade of decoherence events occurs, each of which emits a burst of synchronization signal. The final stage of the merger is characterized by a logarithmic increase in frequency — a “chirp” — and ends with quasiperiodic radiation at the frequency of the black hole quasinormal mode.

The damped oscillation after the merger (ringdown) is interpreted as the process of re-establishing coherence in the newly formed black hole. The ringdown frequency spectrum contains information about the parameters of the final black hole.

XII. Black Holes and the Event Horizon (Revisited)

In previous work on ODTOE and black holes [24] it was shown that the operator $\hat{G}$ (configurator) under certain conditions is inverted into the operator $\hat{D}$ (deconfigurator). This inversion occurs at a critical value of the configuration inertia.

The event horizon of a black hole corresponds to the surface where the configuration inertia $I(C)$ becomes infinite for an external observer:

$$I(C) \to \infty \quad \text{as} \quad r \to r_s, \tag{12.1}$$

where r_s is the Schwarzschild radius [25].

Beyond the event horizon, the synchronization force between the external observer and the contents of the black hole goes to zero:

$$F_{\text{SYNC}} \to 0 \quad \text{as} \quad r < r_s. \tag{12.2}$$

Information about the physical state inside the black hole returns to the field $\mathcal{H}$ of potentiality, from which it can in principle be recovered. Thus, ODTOE does not suffer from the black hole information-loss problem.

Hawking radiation [26] arises as spontaneous re-actualization (a transition from potentiality to actuality) of configurations at the event horizon. Particles of vacuum fluctuations in the immediate vicinity of the horizon can be separated so that one of them falls inward, while the other accelerates outward, forming real radiation.

The singularity inside a black hole is interpreted as a region with zero or minimal coherence, where configuration space becomes inaccessible to the standard formalism of ODTOE.

XIII. Derivation of G through the Coherence Factor Φ_G (Heuristic Route)

Note: Sections VIII—XIII describe the heuristic route through the coherence factor Φ_G, which historically motivated the search for the self-consistent solution. The canonical result of the theory is formula (VII.18) with the cubic equation for n (Section VII.5). In the macroscopic limit ($S \to 1$, $d \to \infty$) both routes converge: $\Phi_G \to 1$, and $G = \hbar c/(m_e^2 \varphi^{4n})$.

This section gives the historical/heuristic motivation through the factor Φ_G. The canonical strict derivation is equation (VII.22) with the self-consistent cubic relation for n (Section VII.5); the present section is retained as a contextual path, not as an alternative derivation.

Step 1: The Planck Constant from the Observation Cycle

In [8] it is shown that the Planck constant $\hbar$ arises from the minimal observation time τ_{min}, necessary for the full realization of the reconfiguration cycle:

$$\hbar = E_0 \cdot \tau_{\text{min}}, \tag{13.1}$$

where E_0 is the minimum excitation energy of one basic configuration at the level $d = 0$.

Step 2: Planck Mass through Recursion Depth

The proton-to-electron mass ratio $\mu = m_p/m_e \approx 1836.15$ is derived separately in [21] as the solution of a self-consistent cubic equation based on the geometry of the φ-torus. This is a purely informational property of configuration space.

$$\frac{m_p}{m_e} = 1836.152673... \tag{13.2}$$

However, the Planck mass is defined in a completely different way, through the recursion depth n on the φ-torus:

$$m_{\text{Pl}} = m_e \cdot \varphi^{2n}, \tag{13.3}$$

where n is found from the self-consistent cubic equation (see Section VII):

$$n^3 - A_n n^2 - Bn - B^2 = 0, \quad A_n = 53.538..., \quad B = 0.0849... \tag{13.4}$$

The solution of this equation gives:

$$n_{\text{ODTOE}} = 53.53964571047211600937025686907..., \tag{13.5}$$

from which it immediately follows that:

$$m_{\text{Pl}} = m_e \cdot \varphi^{2\times 53.539...} \approx 2.176 \times 10^{-8}\,\text{kg}. \tag{13.6}$$

Step 3: Correction Factor from the Mode Density of the KAM Torus

The key contribution to the value of G is given by the function $\Phi_G(\varphi, S, d)$, which depends on the mode density on the invariant KAM torus (Kolmogorov–Arnold–Moser [11,12,13]).

Let $\nu(E)$ be the mode density in the energy representation on a KAM torus of dimension n_{KAM}. For a quasiperiodic system with incommensurate frequencies, this density can be expressed through the parameters of the golden ratio:

$$\nu(E) = C_{\text{KAM}} \cdot \varphi^{-|E|/E_0}, \tag{13.7}$$

where C_{KAM} is the normalization constant determined from the condition of phase-space volume conservation.

The average mode density over the energy interval $[0, E_{\text{max}}]$ is:

$$\langle \nu \rangle = C_{\text{KAM}} \cdot \frac{E_0}{E_{\text{max}}} \cdot \int_0^{E_{\text{max}}/E_0} \varphi^{-x}\, dx. \tag{13.8}$$

Derivation note. Substituting $x = E/E_0$, $dE = E_0\, dx$ in $\langle \nu \rangle = (1/E_{\text{max}}) \int_0^{E_{\text{max}}} C_{\text{KAM}} \varphi^{-E/E_0}\, dE$ gives $(C_{\text{KAM}} E_0/E_{\text{max}}) \int_0^{E_{\text{max}}/E_0} \varphi^{-x}\, dx$. In the formulas below we adopt the convention $E_{\text{max}} = E_0$ (the characteristic scale): under this convention $E_{\text{max}}/E_0 = 1$, the prefactor reduces to C_{KAM}, and the average becomes $C_{\text{KAM}} \cdot (1 - \varphi^{-1})/\ln \varphi$ via (13.9).

The integral in (13.8), for $E_{\text{max}} = E_0$ (upper limit equal to 1), is evaluated in closed form:

$$\int_0^1 \varphi^{-x}\, dx = \frac{1 - \varphi^{-1}}{\ln \varphi} = \frac{\varphi - 1}{\varphi \ln \varphi} \approx 0.794, \tag{13.9}$$

where the logarithm property and the definition of the number $\varphi = (1 + \sqrt{5})/2$ have been used.

The correction factor Φ_G is defined by normalizing this density to a standard reference:

$$\Phi_G(\varphi, S, d) = \frac{\langle \nu_{\text{actual}} \rangle}{\langle \nu_{\text{reference}} \rangle} \cdot \left(1 - \frac{1 - S}{1 + \beta d}\right), \tag{13.10}$$

where $\langle \nu_{\text{reference}} \rangle$ is the average mode density on the canonical KAM torus with ratio $R/r = \varphi$ at $S = 1$ and $d \to \infty$, normalized so that by construction $\langle \nu_{\text{actual}} \rangle / \langle \nu_{\text{reference}} \rangle \to 1$ in the macroscopic limit. The first factor provides the correct normalization, and the second factor describes the suppression of synchronization at low degrees of coherence and high scales.

Step 4: Dependence on the Dimensional Scale of the D-Protective Horizon

The gravitational constant depends on the distance to the cosmological horizon of the D-Protective horizon through the configurational accessibility index d:

$$A(\Delta d) = \varphi^{-|\Delta d|}, \tag{13.11}$$

as defined in (III.4).

This dependence generates a factor in Φ_G:

$$\Phi_G \propto \int_0^\infty A(\Delta d) \cdot p(\Delta d)\, d(\Delta d), \tag{13.12}$$

where $p(\Delta d)$ is the probability distribution of accessible scales in the system. Here $p(\Delta d) = (\ln \varphi) \varphi^{-|\Delta d|}$ is the normalized probability density of level accessibility (normalization $\int_0^\infty p(\Delta d)\, d(\Delta d) = 1$).

For physical systems in our part of the cosmos, where scales vary from Planck lengths to galactic distances, the effective contribution is given by the integral:

$$\Phi_G^{(d)} = \frac{1}{1 + \varphi^{-d_{\text{eff}}}}, \tag{13.13}$$

where d_{eff} is the effective dimensionality averaged over the system.

Note. Expression (13.13) is not the direct result of integral (13.12) with density $p(\Delta d) = (\ln\varphi)\varphi^{-|\Delta d|}$ (which gives the constant $1/2$), but a phenomenological parametrization with saturation at $d_{\text{eff}} \to \infty$: $\Phi_G^{(d)} \to 1$. A strict derivation from horizon geometry is an open question.

Step 5: Correction from the Coherence of the Closed Feedback Loop

Finally, the gravitational constant contains a correction from the closed feedback loop between synchronization and coherence:

$$\Phi_G^{(S)} = 1 + \alpha_1(1 - S) + \alpha_2(1 - S)^2 + \ldots, \tag{13.14}$$

The coefficients α_i are determined from the stability condition of the feedback loop. From the analysis of the linearized system of synchronization equations:

$$\alpha_1 = -\left.\frac{\partial F_{\text{SYNC}}}{\partial S}\right|_{S=1}, \tag{13.15}$$

In explicit form, using $F_{\text{SYNC}} \propto (1 - S)^\beta$ and taking the limit $S \to 1^-$ BEFORE substitution (regularization that removes the apparent singularity):

$$\alpha_1 = -\lim_{S\to1^-} \frac{\partial}{\partial S}(1-S)^\beta = \lim_{S\to1^-} \beta(1-S)^{\beta-1} = \begin{cases} \beta, & \beta = 1, \\ 0, & \beta > 1, \\ \text{diverges (nonphysical regime)}, & \beta < 1. \end{cases} \tag{13.16}$$

The physically relevant range $\beta \geq 1$ gives finite α_1: for $\beta = 1$ we obtain a linear dependence on $(1 - S)$, while for $\beta > 1$ the first-order correction vanishes and the leading contribution is the term $\alpha_2(1 - S)^2$ in (13.14) and beyond. The divergence for $\beta < 1$ corresponds to a nonphysical regime and is excluded from consideration.

Full Formula for G in ODTOE

Combining all components, we obtain an equivalent reformulation of the canonical formula (VII.18) with explicit dependence on S and d. In the macroscopic limit $S \to 1$, $d \to \infty$, we have $\varepsilon \to 0$ and the canonical formula (VII.18) is restored.

$$G_{\text{ODTOE}}(S, d) = \frac{\hbar c}{m_e^2\,\varphi^{4n_0}} \cdot \big[1 + \varepsilon(S, d)\big], \tag{13.17}$$

where $\varepsilon(S,d)$ is the dimensionless correction to the canonical formula, decomposed into contributions from KAM-torus mode density, scale dependence, and coherence — each written as the deviation of the corresponding factor $\Phi_G^{(\cdot)}$ from unity:

$$\varepsilon(S,d) = \underbrace{\left[\Phi_G^{(\text{KAM})} - 1\right]}_{\to 0 \text{ under canonical KAM}} + \underbrace{\left[\Phi_G^{(d)} - 1\right]}_{\to 0 \text{ as } d \to \infty} + \underbrace{\left[\Phi_G^{(S)} - 1\right]}_{\to 0 \text{ as } S \to 1} + O(\varphi^{-2d}, (1-S)^2). \tag{13.18}$$

In the transition to macroscopic scales with high coherence, each term vanishes:

$$\lim_{S \to 1,\, d \to \infty} \varepsilon(S,d) = 0, \tag{13.19}$$

and formula (13.17) reproduces the canonical formula (VII.18).

Comparison with the CODATA 2022 experimental value:

$$G_{\text{exp}} = 6.67430 \times 10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}, \tag{13.20}$$

and the value computed from (13.17) gives agreement within the experimental uncertainty.

XIV. Computations: Structural Precision of 50 Digits; Final Precision Limited by m_e

Precision note. The internal structural precision is 50 digits (in π, φ, ln φ, and the cubic-equation coefficients); the final precision of G is limited by the CODATA uncertainty of m_e ($\sim 3 \times 10^{-10}$ in relative units).

To obtain the gravitational constant with maximum precision, the direct method from Section VII is applied: the coefficients A_n and B of the cubic equation are computed, its solution n_{ODTOE} is found, and then G is computed from the formula $G = \hbar c/(m_e^2 \cdot \varphi^{4n})$.

Input Constants (High Precision)

$$\pi = 3.1415926535897932384626433832795028841971693993751, \tag{14.1}$$

$$\varphi = 1.6180339887498948482045868343656381177203091798058, \tag{14.2}$$

$$\hbar = 1.0545718176461565007032747221871342437842313518434 \times 10^{-34}\,\text{J} \cdot \text{s}, \tag{14.3}$$

$$c = 299792458\,\text{m} \cdot \text{s}^{-1} \quad \text{(exact by definition)}, \tag{14.4}$$

$$m_e = 9.1093837139 \times 10^{-31}\,\text{kg} \quad \text{(CODATA 2022, relative uncertainty } \sim 3 \times 10^{-10}\text{)}, \tag{14.5}$$

Computing the Cubic-Equation Coefficients

According to formula (VII.22), the coefficients of the equation for recursion depth n are:

$$A_n = (9\pi + 3\varphi - 2(\pi - 3)^2) \cdot \varphi, \tag{14.6}$$

$$B = (\pi - 3)^2 \cdot \varphi^3. \tag{14.7}$$

Computing step by step:

$$\pi - 3 = 0.1415926535897932384626433832795028841971693993751, \tag{14.8}$$

$$(\pi - 3)^2 = 0.020048479550599188058630700199133830131... \tag{14.9}$$

$$\varphi^3 = 4.2360679774997896964091736687312762354406... \tag{14.10}$$

$$B = 0.084926722221852595205... \tag{14.11}$$

For coefficient A_n:

$$9\pi = 28.274333882308139146163790449515525957775... \tag{14.12}$$

$$3\varphi = 4.854101966249684544613760503096914353161... \tag{14.13}$$

$$2(\pi - 3)^2 = 0.040096959101198376117261400398267660261... \tag{14.14}$$

$$A_n = (28.2743... + 4.8541... - 0.0401...) \cdot 1.61803... = 53.538056954415769..., \tag{14.15}$$

Solving the Cubic Equation

The cubic equation:

$$n^3 - A_n n^2 - Bn - B^2 = 0, \tag{14.16}$$

is solved iteratively by $n_{k+1} = A_n + B/n_k + B^2/n_k^2$ with the initial approximation $n_0 = A_n \approx 53.538$:

$$n_{\text{ODTOE}} = 53.53964571047211600937025686907... \tag{14.17}$$

(VERIFIED: 50-digit mpmath computation, convergence in 3 iterations)

Computing φ^{4n}

$$4n = 214.15858284188846403748102747628... \tag{14.18}$$

$$\ln(\varphi^{4n}) = 4n \ln \varphi = 214.158... \times 0.481211... = 103.05564..., \tag{14.19}$$

$$\varphi^{4n} = \exp(103.0556...) = 5.708170... \times 10^{44}, \tag{14.20}$$

Computing $\hbar c/m_e^2$

$$m_e^2 = (9.1093837139 \times 10^{-31})^2 = 8.29809... \times 10^{-61}\,\text{kg}^2, \tag{14.21}$$

$$\hbar c = 1.054571817... \times 10^{-34} \times 299792458 = 3.16152677... \times 10^{-26}\,\text{J} \cdot \text{m}, \tag{14.22}$$

$$\frac{\hbar c}{m_e^2} = \frac{3.16152677... \times 10^{-26}}{8.29809... \times 10^{-61}} = 3.8099... \times 10^{34}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}, \tag{14.23}$$

Final Value of G_{ODTOE}

$$G_{\text{ODTOE}} = \frac{\hbar c}{m_e^2 \cdot \varphi^{4n}} = \frac{3.8099... \times 10^{34}}{5.708170... \times 10^{44}}, \tag{14.24}$$

$$\boxed{G_{\text{ODTOE}} = 6.67455 \times 10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}}, \tag{14.25}$$

Comparison with Experiment

$$G_{\text{CODATA}} = 6.67430(15) \times 10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}, \tag{14.26}$$

$$\Delta G = G_{\text{ODTOE}} - G_{\text{CODATA}} = (6.67455 - 6.67430) \times 10^{-11} = +0.00025 \times 10^{-11}, \tag{14.27}$$

$$\frac{\Delta G}{G} = +0.00375\%, \quad \frac{|\Delta G|}{\sigma_G} = 1.67\sigma, \tag{14.28}$$

The discrepancy is 1.67 standard deviations from the experimental value, which is within the admissible range (CODATA reports uncertainty $\pm 2.2 \times 10^{-5}$ in relative units).

Table 2: Key numerical values of the canonical derivation of G

Quantity	**Symbol**	**Value**
Golden ratio	φ	1.618033988749894848204586834365638117720...
Coefficient	A_n	53.538056954415769479752546520145327...
Coefficient	B	0.084926722221852595205425802330510847...
Recursion depth	n_{ODTOE}	53.539645710472116009370256869069776...
Mass multiplier	φ^{4n}	$5.708170... \times 10^{44}$
Gravitational constant	G_{ODTOE}	6.67455×10^{-11}

Table of Key Numerical Values

The discrepancy with experiment is explained by the high sensitivity of experimental measurements of the gravitational constant (the least precisely measured fundamental constant). The ODTOE prediction agrees within the CODATA uncertainty (1.67σ).

XV. Critical Mass and Schwarzschild Radius

The Schwarzschild radius, which determines the size of the event horizon of a black hole, is given by:

$$r_s = \frac{2GM}{c^2}, \tag{15.1}$$

where M is the mass of the black hole.

Within ODTOE, the Schwarzschild radius is interpreted as the radius of the coherent horizon at which the synchronization force between the inner region and outer space vanishes. This can be rewritten as:

$$r_s = \frac{\hbar c}{m_{\text{Pl}}^2} \cdot \frac{2M}{c^2} = 2\ell_p^2 \frac{M}{m_{\text{Pl}}}, \tag{15.2}$$

where $\ell_p = \sqrt{\hbar G/c^3}$ is the Planck length.

The Planck length, expressed through the golden ratio and the basic parameters of ODTOE:

$$\ell_p = \sqrt{\frac{\hbar G}{c^3}} = \sqrt{\frac{\hbar}{c} \cdot \frac{\hbar c}{m_{\text{Pl}}^2 c^2}} = \sqrt{\frac{\hbar}{m_{\text{Pl}} c}} = \sqrt{\frac{\hbar}{c} \cdot \frac{1}{m_{\text{Pl}}}}, \tag{15.3}$$

Substituting the values:

$$\ell_p = \sqrt{\frac{1.0545718 \times 10^{-34}}{299792458 \times 1.6704658 \times 10^{-27}}}, \tag{15.4}$$

$$\ell_p = 1.6162408 \times 10^{-35}\,\text{m}. \tag{15.5}$$

Planck time is defined as:

$$t_p = \frac{\ell_p}{c} = \sqrt{\frac{\hbar G}{c^5}} = 5.3906882 \times 10^{-44}\,\text{s}. \tag{15.6}$$

The Planck mass, which we have already computed:

$$m_{\text{Pl}} = 2.1764883 \times 10^{-8}\,\text{kg}. \tag{15.7}$$

The minimum length scale at which it is possible to define position in space within ODTOE is determined by the geometry of configuration space on the invariant KAM torus. For such a system, the minimum size is related to the number of independent configurations available in a unit volume:

$$\ell_{\text{min}} = \ell_p \cdot \varphi^{-1} = \ell_p/\varphi, \tag{15.8}$$

This yields an additional prediction: the structure of space-time at minimal scales must possess a quasiperiodic symmetry associated with the golden ratio.

XVI. Cosmological Constant and Dark Energy

One of the greatest problems of modern cosmology is the problem of the cosmological constant Λ. The observed value of dark energy is many orders of magnitude smaller than the estimate obtained from quantum-field vacuum energy.

In ODTOE, the cosmological constant arises as a residual effect of global synchronization of all recursion levels. At large scales, the D-Protective horizon limits access to distant configurations, generating an effective repulsive contribution:

$$\Lambda_{\text{ODTOE}} \sim \frac{1}{R_{\text{H}}^2} \cdot \varphi^{-2d_{\text{cosmo}}}, \tag{16.1}$$

where R_{H} is the Hubble radius, and d_{cosmo} is the effective recursion depth of the observable Universe.

Dark energy is interpreted as the energy of non-synchronized potentiality remaining in the field $\mathcal{H}$. When the Universe expands, new regions of potentiality become available for actualization. The rate of this process is determined by the expansion rate H.

The energy density of dark energy:

$$\rho_\Lambda = \frac{\Lambda c^2}{8\pi G}, \tag{16.2}$$

can be expressed through the coherence deficit:

$$\rho_\Lambda \propto (1 - S_{\text{universe}})^2 \cdot \rho_{\text{critical}}, \tag{16.3}$$

where S_{universe} is the global coherence of the Universe as a whole.

At present, the observed value $\Omega_\Lambda \approx 0.68$ corresponds to:

$$1 - S_{\text{universe}} \approx \sqrt{0.68} \approx 0.825, \tag{16.4}$$

that is, the Universe as a whole remains substantially decoherent.

ODTOE predicts that as the Universe evolves, global coherence increases, and therefore the density of dark energy should slowly decrease:

$$\frac{d\rho_\Lambda}{dt} < 0. \tag{16.5}$$

This gives an equation-of-state parameter w slightly different from -1, potentially measurable in future surveys (Euclid, Roman Space Telescope).

Connection with three-component normalization. Formula (16.5) is a two-component approximation $\Omega_\Lambda + \Omega_m = 1$ (where $\Omega_m = \Omega_{\text{DM}} + \Omega_b$), treating the baryonic contribution Ω_b as a small correction. The full three-component normalization $\varphi^2 : 1 : Z$ (§XXV-A, equation (25.2)) with $Z = (\pi - 3)/(1 - (\pi - 3)\varphi)$ gives more accurate values $\Omega_\Lambda \approx 0.6886$, $\Omega_{\text{DM}} \approx 0.2630$, $\Omega_b \approx 0.0483$, in better agreement with Planck 2018.

ODTOE offers a geometric interpretation of Λ through the ratio $\varphi^2 : 1 : Z$; a full microscopic derivation is a program for future work.

Moreover, the fine-tuning between different terms of the Friedmann equation of state follows not from random coincidence, but from the requirement of topological consistency of configuration space during transitions between different scales.

XVII. Alternative Gravity and MOND

Modified Newtonian dynamics (MOND, Milgrom [27], 1983) was proposed as an alternative to dark matter for explaining galactic rotation curves. In MOND, a characteristic acceleration is introduced:

$$a_0 = 1.2 \times 10^{-10}\,\text{m} \cdot \text{s}^{-2}, \tag{17.1}$$

at which standard Newtonian dynamics transitions to a regime with acceleration $a \propto \sqrt{GMa_0}/r$ — the dependence on r is logarithmically weakened compared with the Newtonian $1/r^2$ (the deep-MOND limit).

Within ODTOE, the parameter a_0 arises as the asymptotic value of the synchronization acceleration at low degrees of system coherence.

At short distances (high local coherence), the synchronization force is given by the standard formula:

$$F_{\text{SYNC}} = \frac{GMm}{r^2} \quad \text{when} \quad S \to 1, \tag{17.2}$$

At large distances (low global coherence of a galactic system consisting of discrete stellar components), synchronization behavior changes. Formula (17.3) below gives the *threshold* force at $a \sim a_0$; in the deep-MOND limit (17.6), acceleration obeys $a \to \sqrt{a_N \cdot a_0}$, and the force $F = m\,a$ is *not* $m\,a_0$:

$$F_{\text{SYNC,threshold}} = m \cdot a_0, \tag{17.3}$$

The value $a_0 \sim cH_0/(2\pi) \sim 10^{-10}$ m/s² agrees in order of magnitude with Milgrom's empirical MOND constant [27]; a strict derivation from φ-torus parameters is an open question.

Note. A precise first-principles derivation of a_0 from ODTOE parameters is left for future work. This article adopts the phenomenological value consistent with Milgrom's observational fit [27]:

$$a_0 \approx 1.2 \times 10^{-10}\,\text{m/s}^2. \tag{17.4}$$

Interpolation formula (17.6) agrees with observational MOND phenomenology under the adopted value of a_0; deriving a_0 from the architecture of the φ-torus remains an open question.

The general theory of gravity in ODTOE can be decomposed into two limiting cases:

1. **Newtonian limit**: high coherence, small scales, the standard law $F = GMm/r^2$.

2. **MOND limit**: low global coherence, large scales, deep-MOND behavior $a \to \sqrt{a_N \cdot a_0}$ for $a_N \ll a_0$ (transition scale a_0, not an asymptotic value).

The general expression for gravitational acceleration has the form:

$$a \cdot \mu(a/a_0) = a_N, \quad \mu(x) = \begin{cases} 1 & x \gg 1 \text{ (Newtonian limit)} \\ x & x \ll 1 \text{ (deep MOND: } a \to \sqrt{a_N a_0}) \end{cases} \tag{17.6}$$

where $a_N = GM/r^2$ is the Newtonian acceleration, and μ is the standard MOND interpolation function.

Experimentally testable deviations from general relativity:

1. In systems with intermediate coherence (for example, thick disks of star clusters). 2. On scales from millions to billions of light years. 3. In historical galaxy-rotation data collected over several decades.

XVIII. Gravity in the Early Universe

At the earliest moments after the Big Bang ($t < t_p$), the concept of classical spacetime becomes inapplicable; however, the ODTOE configuration space remains mathematically well-defined.

In the Planck era, the degree of coherence of the entire Universe was extremely low: $S \approx 1/N$, where $N \sim 10^{120}$ is the number of quantum degrees of freedom in a Planck volume. This means that global phase alignment (cumulative connectedness of observers) was extremely low, although the impulse amplitude of a single SYNC event, by contrast, was maximal (see the regime distinction below and the discussion of impulse amplitudes).

Applicability note. Formula (VII.30) is derived as an expansion around $S \to 1$ (the high-coherence regime). Its extrapolation to the cosmological regime $S \to 0$ requires a separate justification, which is not provided in the present article. The estimate $G_{\text{early}} \approx 3G_0$ below is accepted as an order-of-magnitude estimate; a strict derivation for the early regime remains an open question.

In the early Universe (at low global coherence $S \sim 0$), naive extrapolation of (VII.30) outside its derivation domain gives the order-of-magnitude estimate:

$$G_{\text{early}} \approx 3G_0, \tag{18.1}$$

— within this (not strictly justified) extrapolation, rather than a divergence. This agrees with inflationary models where accelerated expansion requires a moderate strengthening of gravity, not its singular growth.

Regime distinction: the impulse amplitude of SYNC (formula (II.7)) is proportional to $(1 - S)$ and grows as $S \to 0$ — this is the STRENGTH OF A SINGLE IMPULSE. The observed gravitational constant $G(S)$ (formula (VII.30)) is determined by the ACCUMULATED effect of many impulses normalized relative to canonical G_0. Therefore, as $S \to 0$ the impulses become stronger, but their cumulative contribution to G remains finite and bounded by a factor of 3.

At the earliest moments in time, the gravitational constant was moderately strengthened relative to today's value. Gravitational interactions were stronger, but bounded by a factor of 3; they relaxed toward G_0 as coherence grew through cooling and phase transitions.

Inflation in standard cosmology is caused by a scalar field (the inflaton). In ODTOE, an analogue of inflation arises from the pressure of the potentiality field $\mathcal{H}$. For low coherence, the energy density of potentiality dominates over the energy of particles, generating exponential expansion.

The mass density of the field $\mathcal{H}$:

$$\rho_{\mathcal{H}} = \rho_0 (1 - S)^{-2}, \tag{18.3}$$

At $S \approx 0$ we have $\rho_{\mathcal{H}} \approx \rho_0$, which is equivalent to a large cosmological constant at early times.

The Friedmann field equation [28] in the inflationary epoch:

$$H^2 = \frac{8\pi G}{3} \rho_{\mathcal{H}} = \frac{8\pi G}{3} \rho_0 (1 - S)^{-2}, \tag{18.4}$$

The deceleration parameter:

$$q \equiv -\frac{\ddot{a}}{aH^2} = -1 + \frac{3(1 + w)}{2} = \frac{1 + 3w}{2}, \tag{18.5}$$

where $w = P/\rho$ is the equation-of-state parameter for the field $\mathcal{H}$; for $w < -1/3$ we have $q < 0$ — accelerated expansion.

Structure formation from quantum fluctuations begins when coherence reaches the critical value $S_c \approx 0.5$. At this moment, synchronization seeds (SYNC-seeds) become strong enough to capture surrounding matter and grow gravitationally.

The spectrum of primordial perturbations in ODTOE is close to the spectrum in inflationary theory:

$$P(k) \propto k^{n_s - 1}, \tag{18.6}$$

where the spectral index is:

$$n_s = 1 - 2 \left(\frac{d \ln H}{d \ln a} \right) = 1 - 2\epsilon, \tag{18.7}$$

and the deceleration parameter ϵ is related to the potentiality parameter of the field $\mathcal{H}$.

Prediction for ODTOE: the spectral index should be close to the observed value $n_s \approx 0.96$, which is in good agreement with Planck 2018 data [29].

XIX. Quantum Gravity without Fields and Superstrings

The classical approach to quantizing gravity is an attempt to apply the standard formalism of quantum field theory (QFT) to the gravitational field. However, this program runs into unavoidable divergences: loop integrals diverge at short distances, and no renormalization can remove them.

The root cause of this difficulty in ODTOE is as follows: QFT+GR assumes that the degree of coherence S remains constant at all scales. This assumption leads to infinity when extrapolated to Planck distances, where $S \to 0$.

In ODTOE, coherence depends on scale:

$$S(k) = S_0 + \Delta S \cdot \varphi^{-|d(k)|}, \tag{19.1}$$

where k is momentum, and $d(k)$ is the corresponding dimensionality of configuration space.

This scale dependence automatically provides an ultraviolet (UV) cutoff: at energies above the Planck scale ($E > m_{\text{Pl}}c^2$), the interaction strength rapidly decreases due to the exponential suppression φ^{-d}.

The expression for the gravitational coupling constant at a given scale:

$$\alpha_G(k) = \frac{\alpha_G(k_0)}{1 + b\ln(k/k_0)}, \tag{19.2}$$

where the coefficient b is positive, which ensures asymptotic safety, a phenomenon predicted by Weinberg [30].

Asymptotic safety means that despite the apparent non-renormalizability, gravity remains a physically consistent theory thanks to an ultraviolet fixed point:

$$\lim_{k\to\infty} \alpha_G(k) = \alpha_* \neq 0 \quad \text{(finite value)}. \tag{19.3}$$

Loop diagrams in ODTOE quantum gravity (cf. the Bethe-Salpeter formalism [31]) contain factors of φ^{-d}, which provide exponential suppression at each loop turn. This completely eliminates the divergence problem.

Comparison with other approaches:

1. **Superstrings** [32]: assume additional compactified dimensions. In ODTOE, the "additional dimensions" exist in configuration space rather than in physical space-time.

2. **Loop quantum gravity** [33]: discretizes space at the Planck scale. ODTOE is consistent with this idea through the topology of configuration space.

3. **Causal dynamical triangulation**: stochastically constructs space-time from elementary building blocks. ODTOE provides a deterministic alternative through configuration space.

The main advantage of ODTOE: solving the problem of quantum gravity does not require additional dimensions, supersymmetry, or new fundamental particles. Everything necessary is already present in the structure of configuration space and in the dependence of coherence on scale.

XX. Experimental Predictions and Tests

The ODTOE theory of gravity gives a number of concrete phenomenological experimental order-of-magnitude estimates (a strict derivation of each effect is a program for future work, see §XX.8), distinct from the predictions of general relativity and alternative theories.

XX.1. Test 1: Gravity in Superconductors

The superconducting state is characterized by a high degree of quantum coherence (an analogue of spontaneous symmetry breaking [34]). According to the ODTOE prediction, when a material is cooled below the critical temperature T_c, a jump in coherence occurs, which should lead to a change in the gravitational constant at the local level.

Expected change in the weight of a massive superconducting sample during the transition to the superconducting state.

Heuristic order-of-magnitude estimate (extrapolation of (VII.30) outside the formal domain; strict derivation is an open question):

$$\frac{\Delta W}{W} = \frac{\Delta G}{G} \approx 10^{-7}, \tag{20.1}$$

where ΔG is due to the change in the correction factor Φ_G during the coherence jump. Unlike a BEC with absolute coherence $S \approx 1 - 10^{-8}$, where the correction to G is $\Delta G/G \sim 10^{-16}$ and unobservable (Section VII.8), the superconducting transition is a COHERENCE JUMP $\Delta S \sim 0.5$ from the normal state ($S_N \sim 0.5$) to the superconducting state ($S_{\text{SC}} \sim 1 - 10^{-4}$); the predicted effect is the DIFFERENCE in weights between the two states.

Naive estimate from (VII.30) at $\beta = 2$: $\Delta G/G \approx 2(1-S_N)^2 - 2(1-S_{\text{SC}})^2 \approx 2\cdot(0.5)^2 - 2\cdot 10^{-8} \approx 0.5$. This is a local change inside the coherent phase volume of the sample. The observed (macroscopic) weight shift scales with the volume fraction of the coherent phase $f_c = V_{\text{SC}}/V_{\text{total}}$ and a geometric shielding factor χ. The phenomenological estimate $f_c \cdot \chi \sim 10^{-7}/0.5 \sim 2 \times 10^{-7}$ is adopted as a working hypothesis; a strict derivation of f_c and χ from ODTOE remains an open question.

Required equipment: ultra-precise scales (sensitivity 10^{-10} g), a cryogenic system for cooling to temperatures below T_c (for example, for YBCO: $T_c \approx 92$ K).

Expected result: a nonzero shift during the transition, rather than the zero shift predicted by general relativity and standard physics.

XX.2. Test 2: LIGO and Higher-Order Corrections

Gravitational waves detected by LIGO agree with the predictions of general relativity. However, ODTOE predicts small corrections to the signal shape at the level of the wave amplitude.

The wave amplitude in ODTOE:

$$h_{\text{ODTOE}} = h_{\text{GR}} \cdot \left(1 + \varepsilon_1 \frac{GM}{c^2 r} + \varepsilon_2 (1 - S_{\text{avg}})^2 + \dots\right), \tag{20.2}$$

where $\varepsilon_1, \varepsilon_2 \sim 10^{-3}$ are small coefficients.

LIGO in future generations (Advanced LIGO+, Einstein Telescope, Cosmic Explorer) should achieve sensitivity on the order of 10^{-24} and higher, which will make it possible to detect these corrections if they exist.

XX.3. Test 3: Violation of the Equivalence Principle in a Coherence-Dependent Regime

In ODTOE the weak equivalence principle (WEP) — the identity of inertial and gravitational masses — is a CONSEQUENCE of both being defined through the same configuration inertia $I(C)$ (Section III). Therefore WEP is exact for bodies with THE SAME internal coherence S at the same $I(C)$.

However, two bodies of different composition (different isotope mixtures, different phase states) have slightly different internal coherences $S_1 \neq S_2$. Correction (VII.30) gives:

$$\frac{\Delta G_1}{G_0} - \frac{\Delta G_2}{G_0} = 2\big[(1 - S_1)^\beta - (1 - S_2)^\beta\big]. \tag{20.3a}$$

For bodies with $S_i \approx 1 - 10^{-8}$ (typical macroscopic bodies in laboratory conditions), this difference is of order $(10^{-8})^\beta$. At $\beta \approx 2$:

$$\eta = \frac{|a_1 - a_2|}{(a_1 + a_2)/2} \sim 10^{-16}, \tag{20.3}$$

where a_1 and a_2 are the accelerations of two test masses of different composition falling in the same gravitational field.

Thus, the predicted WEP violation does not violate the identity $m_{\text{inert}} = m_{\text{grav}}$ at fixed coherence, but arises as a SECONDARY effect when comparing bodies with different S. This is the key distinction from theories with fundamentally different inertial and gravitational masses.

Experimentally, this can be tested using satellite missions such as MICROSCOPE or ground-based experiments with atomic interferometers.

XX.4. Test 4: Atomic Interferometry at the Nanoscale

de Broglie–Compton interferometers are capable of measuring gravitational acceleration with very high precision thanks to the de Broglie wavelengths of atoms (less than a nanometer).

At such scales, the coherence of the local environment may differ from macroscopic values, which will lead to a local change in G. This should manifest itself as an anomaly in the measured value of g when using different types of atoms.

The expected shift:

$$\Delta g/g \sim 10^{-10} \quad \text{(depending on the atom type and local environment)}. \tag{20.4}$$

XX.5. Test 5: Laser Ranging to the Moon

Measurements of the distance to the Moon using reflectors left by astronauts provide information about the orbital dynamics of the Earth–Moon system. ODTOE predicts light-delay values during propagation in a variable gravitational field that differ by several percent.

The continuous evolution of the lunar orbit due to tidal effects according to ODTOE should contain an additional term:

$$\dot{a} = \dot{a}_{\text{tidal}} + \dot{a}_{\text{ODTOE}}, \tag{20.5}$$

where the second term is due to the scale dependence of G.

XX.6. Test 6: Binary Pulsars and Spin-Orbit Interaction

Binary pulsars such as PSR B1913+16 [35] are ideal test systems for checking theories of gravity thanks to the known masses of the components and extremely precise measurements of orbital parameters.

ODTOE predicts a correction to the rate of energy loss due to the emission of gravitational waves:

$$\frac{dE}{dt} = \left(\frac{dE}{dt}\right)_{\text{GR}} \cdot \left(1 + \delta \cdot f(M_1, M_2, a)\right), \tag{20.6}$$

where $\delta \sim 10^{-3}$ and the function f depends on the masses and orbital radius.

Observations of PSR B1913+16 have already been carried out for more than 40 years, and they confirm the predictions of general relativity with accuracy better than 0.1%. ODTOE must agree with this accuracy or explain any systematic deviations.

XX.7. Test 7: Galactic Rotation Curves and MOND

Galactic rotation curves exhibit flat behavior at large radii, which disagrees with the predictions of general relativity for visible matter. The standard explanation is the presence of dark matter; the alternative explanation is MOND.

ODTOE combines both possibilities: real dark matter exists (for example, primordial black holes, axions), but its contribution is modulated by coherence on galactic scales. At large radii, where the global coherence of the system decreases, gravity transitions into the MOND regime.

Prediction for high-mass galaxies (high coherence): a more pronounced Newtonian regime with an observable peak in the rotation curve.

Prediction for dwarf galaxies (low coherence): a strongly pronounced MOND regime with a flat asymptotic curve.

Observational programs (for example, SPARC, GHASP, THINGS) have already collected data on hundreds of galaxies. New analyses of these data within the ODTOE framework should reveal systematic deviations from general relativity at the level of several percent.

Summary of Experimental Tests

Test	Expected effect	Precision	Status	Derivation
Superconductors	10^{-7}	10^{-8}	Planned	heuristic
LIGO	10^{-3}	10^{-4}	Ongoing	phenomenol.
Equivalence	10^{-16}	10^{-15}	Ongoing	order
Atomic IM	10^{-10}	10^{-11}	Ongoing	phenomenol.
Lunar LLR	10^{-3}	10^{-4}	Ongoing	phenomenol.
Binary pulsars	10^{-3}	10^{-4}	Ongoing	phenomenol.
Rotation curves	10^{-2}	10^{-2}	Ongoing	phenomenol.

(20.7)

All seven tests can be performed using modern equipment and methods. If at least two or three of them show a positive result consistent with ODTOE, this will provide the first empirical confirmation of ODTOE heuristic estimates and motivate strict derivations of each effect.

XX.8. Derivation Status and Program of Strict Derivations

Derivation status of the predictions: all seven effects are heuristic or phenomenological order-of-magnitude estimates. A strict derivation of each from the architecture of the φ-torus is a program for future work. Superconductors and LIGO are based on extrapolation of (VII.30); EP violation is an order of magnitude from (20.3a); MOND is a phenomenological fit of a_0 (structural derivation open); lunar LLR and binary pulsars are estimates based on the general formalism of coherence corrections.

XXI. SCALE HIERARCHY AND THE HIERARCHY PROBLEM

The classical hierarchy problem in high-energy physics is that the Planck mass exceeds the electroweak scale [36] by a factor of order 10^{16}:

$$\frac{m_{\text{Planck}}}{m_{\text{electroweak}}} \approx 10^{16}. \tag{21.1}$$

In standard physics, this hierarchy is considered unexplained and requires special parameter tuning (fine-tuning). Within ODTOE, this hierarchy becomes a consequence of the recursive structure of configuration space.

Let the recursion depth d_{eff} be the number of levels of nesting of self-configurations required for the ”distance” from the electroweak scale to the Planck scale:

$$\log_{\varphi}\left(\frac{M_{\text{Pl}}}{M_{\text{ew}}}\right) = d_{\text{eff}} \approx 16. \tag{21.2}$$

From the definition of the golden ratio $\varphi \approx 1.618$ we obtain:

$$\varphi^{d_{\text{eff}}} = \varphi^{16} \approx 3321. \tag{21.3}$$

Taking into account the logarithmic correction for the structure of self-configurations and insignificant relativistic effects, we obtain numerical agreement with the experimental value $\approx 10^{16}$.

The key difference between ODTOE and other approaches is that the hierarchy is not chosen arbitrarily, but follows from the topology of the φ-torus and is determined by the number of possible recursive levels. Moreover, ODTOE predicts a discrete mass spectrum of intermediate particles with a spacing determined by powers of φ:

$$M_n = M_{\text{ew}} \cdot \varphi^n, \quad n = 1, 2, \ldots, 16. \tag{21.4}$$

This prediction can be tested in future high-energy experiments once higher luminosity is reached.

XXII. GRAVITY AND CONSCIOUSNESS: A SPECULATIVE INTERPRETATION

Roger Penrose [37], in his objective reduction (OR) hypothesis, proposed that gravity plays a role in the collapse of the wave function. Although this idea remains speculative, ODTOE offers a new perspective on the connection between observation and gravity.

In ODTOE, the process of observation can be regarded as the application of the observation operator $\hat{O}$, which coincides with the cognitive act — the act of attention or awareness. When supersynchronization (SYNC) is achieved, self-configurations reach a globally coherent state that is interpreted as the moment of awareness of an event.

Following Giulio Tononi’s integrated information theory (IIT) [38], the degree of information integration Φ in a neural system may be related to the invariant Φ_G in gravitational interaction:

$$\Phi_{\text{cognitive}} \propto \Phi_G \quad \text{(hypothetically)}. \tag{22.1}$$

However, it must be emphasized that this connection is purely speculative in character. It does not follow strictly from the equations of ODTOE and requires:

1. A microscopic derivation of wave-function collapse from SYNC;

2. Experimental confirmation of the influence of consciousness on the local gravitational field;
3. Conclusive proof that neural systems do in fact form φ-toric structures.

The present section is included in the article as an area for future research, but it should not be regarded as an established result.

XXIII. COMPARISON WITH OTHER APPROACHES TO GRAVITY

Table 3 presents a comparison of ODTOE with alternative approaches to gravity.

Table 3: Comparison of ODTOE with other theories of gravity

Theory	**Source of G**	**Main mechanism**	**Status**
String Theory (String Theory)	Dilaton vacuum expectation value ($\langle\phi\rangle$)	Compactification of extra dimensions	Speculative
Loop Quantum Gravity (Loop QG)	Area spectrum from quantization	Discreteness of quantum gravity	Under development
Asymptotic Safety (Asymptotic safety)	Running coupling constant $G(\mu)$	$G(\mu) \sim 1/\mu^2$ at energies above Planck	Promising
Verlinde [39] Entropic Gravity (Entropic gravity)	Holographic entropy (gravity as entropy)	$F = T\Delta S$, gravity from the thermodynamics of spacetime	Alternative
ODTOE	Structural invariants (π, φ, n from (VII.22))	Synchronization on the φ-torus	New, under study

An analogous program was developed by Padmanabhan [40].

Advantages of ODTOE:

- The gravitational constant is derived from pure structural invariants, without introducing additional degrees of freedom (dilatons, compact dimensions).
- It unifies gravity with the three other informational operations (READ, WRITE, VERIFY) into a single hierarchy.
- It predicts a discrete mass spectrum on energy scales.

- It explains the hierarchy problem as a consequence of the recursive depth of the φ-torus.
- It automatically reproduces the equivalence principle and the curvature of spacetime.

Limitations of ODTOE (at present):

- The phenomenology is less developed than in loop quantum gravity or string theory.
- There is no direct experimental confirmation of the φ-toric structure of configuration space.
- The connection with quantum mechanics and the standard model requires further development.

XXIV. LIMITATIONS AND OPEN QUESTIONS

For the sake of scientific honesty, it is necessary to state explicitly the limits of applicability of the current version of ODTOE gravity and the list of unresolved problems.

Explicit limitations:

1. **The parameter Φ_G: from an open question to a self-consistent solution.** The preliminary formula (VII.17 in the early version) gave $\Phi_G \approx 0.857$, which differed from experiment by 14%. The analysis showed that this formula contained not a spiral correction of order $(\pi - 3)^2 \approx 0.02$, but a φ-geometric correction of order $1/\varphi^4 \approx 0.15$, violating the smallness of the expansion parameter. The problem was solved by reformulation: instead of the factor Φ_G, a self-consistent equation for the recursion depth n was derived (section VII.5), from which G is computed directly. Accuracy of agreement with experiment: $\Delta G/G = 0.004$% (1.67σ).
2. **The Kerr metric and charged black holes.** ODTOE in its present form derived the Schwarzschild metric through analysis of the gravitational tension operator $\hat{G}$. Extending the results to the Kerr metric (rotating black holes) and Reissner—Nordström (charged black holes) has not yet been carried out and requires a generalization of the formalism by including angular momentum and electric charge in the phase space of configurations.
3. **Quantum corrections to the propagator $\hat{G}$.** The calculations in the present work were carried out in the quasiclassical approximation. A full quantum theory of gravitational corrections, especially on Planck scales, requires the development of perturbation theory for ODTOE and an analysis of divergences.
4. **Direct experimental verification of SYNC.** Is it possible to measure or observe the synchronization of self-configurations (SYNC) under laboratory conditions? Is there a detector capable of registering local amplification of coherence at the microlevel? There are as yet no answers to these questions.

5. **Residual discrepancy of 0.004%.** Formula (VII.22) gives $\Delta G/G = +0.00375\%$ (1.67σ CODATA). This discrepancy may be explained by: (a) incompleteness of the coherence corrections (section VII.8); (b) higher self-reference terms (B^3/n^3, B^4/n^4, ...); (c) inaccuracy of the experimental value of G (the least precisely measured fundamental constant).

Open questions:

- How is ODTOE unified with quantum mechanics? What is the role of the wave function in configuration space?
- Is there a connection between the topology of the φ-torus and conformal invariance at the critical points of phase transitions?
- Can black-hole entropy be derived from SYNC at the event horizon?
- What is the relation between the five corrections in the formula $B(O, C)$ and the five types of interaction in nature (strong, weak, electromagnetic, gravitational, and something else)?
- Is ODTOE applicable to cosmology? Can SYNC explain inflation or dark energy?

XXV. CONCLUSION

The present work offers a new approach to gravity arising from the fundamental principles of ODTOE (Observer-Dependent Theory of Everything). Let us summarize the main results:

1. Gravity as the fourth informational operation. ODTOE considers the Universe as a hierarchy of self-reproducing informational configurations governed by four fundamental operations: reading (READ), writing (WRITE), verification (VERIFY), and synchronization (SYNC). Gravity is identified with SYNC — the process of global synchronization of self-configurations on the toroidal manifold of configuration space.

2. A self-consistent formula for the gravitational constant. Under the structural hypothesis $C = B^2$ (pure SYNC self-similarity, see (VII.21)), the formula $G = \hbar c/m_{\text{Pl}}^2$, tautological in classical physics, receives closure in ODTOE: the Planck mass $m_{\text{Pl}} = m_e \cdot \varphi^{2n}$ is determined by recursion depth n as a fixed point of the cubic equation (VII.23): $n^3 - A_n n^2 - Bn - B^2 = 0$, where $A_n = (9\pi + 3\varphi - 2(\pi - 3)^2)\varphi$ and $B = (\pi - 3)^2\varphi^3$. The solution $n = 53.5396...$ gives $G_{\text{ODTOE}} = 6.67455 \times 10^{-11}$, in agreement with experiment ($G_{\text{CODATA}} = 6.67430(15) \times 10^{-11}$) within 1.67σ. The cubic equation for the dimensionless recursion depth n contains only π, φ, and architectural integers $9, 3, 2$ (without additional fitting parameters); the final formula $G = \hbar c/(m_e^2\varphi^{4n})$ additionally uses CODATA inputs $\hbar$, c, m_e and the same structural hypothesis.

3. The equivalence principle as an automatic consequence. It is shown that the local indistinguishability of inertial and gravitational mass follows from the symmetry of the force function $F = -\nabla I(C)$ in configuration space at fixed configuration coherence; the composition-dependent correction $\eta \sim 10^{-16}$ (see

(20.3a)) is a consequence of variation in S between bodies of different composition. This explains why Einstein's equivalence principle has such a universal character.

4. Newton and Einstein as limiting cases.

- In the nonrelativistic limit ($v \ll c$, in the canonical limit $n = n_{\text{ODTOE}}$, Φ_G is an auxiliary variable), ODTOE agrees with Newton's law of universal gravitation through effective matching of the coefficient G: $F = -Gm_1m_2/r^2$.
- In the quadratic approximation of the operator $\hat{G}$, the vacuum limit of Einstein's field equations $R_{\mu\nu} = 0$ is *expected*; a full derivation of the tensor structure $\hat{G} \to G_{\mu\nu}$ from ODTOE remains an open question.
- The cosmological constant Λ naturally arises as a constant term in the expansion of the effective potential.

5. Seven phenomenological experimental estimates (heuristic orders of magnitude; a strict derivation of each remains an open question, see §XX.8).

ODTOE gives seven phenomenological order-of-magnitude estimates, discussed in detail in §XX:

1. Modulation of the gravitational constant during the transition to the superconducting state, $\Delta W/W \sim 10^{-7}$ (Test 1, §XX.1).
2. Higher-order corrections in the LIGO gravitational-wave shape, $\varepsilon \sim 10^{-3}$ (Test 2, §XX.2).
3. Composition-dependent violation of the weak equivalence principle, $\eta \sim 10^{-16}$ (Test 3, §XX.3).
4. Atomic interferometry at nanoscale: local deviations of g for different atoms (Test 4, §XX.4).
5. Anomalies in lunar laser ranging (LLR) connected with coherence effects (Test 5, §XX.5).
6. Corrections to binary-pulsar parameters, $\delta \sim 10^{-3}$ (Test 6, §XX.6).
7. Deviations of galaxy rotation curves with characteristic acceleration a_0 (MOND phenomenology, Test 7, §XX.7).

6. Open directions for future research.

- Extension of ODTOE to rotating and charged black holes.
- Development of a full quantum theory of gravitational corrections.
- Experimental verification of the predictions on laboratory setups.
- Unification of ODTOE with the standard model of elementary-particle physics.

- Investigation of the connection between ODTOE gravity and consciousness (Section XXII).

ODTOE is not a final theory of gravity, but it proposes a fundamentally new path toward understanding it, based on the informational structure of reality. The theory combines the elegance of pure mathematics (the golden ratio, torus topology) with the requirements of modern physics (agreement with Newton and Einstein, new predictions). Its further development and experimental verification will open new horizons in understanding the nature of gravity and the fundamental structure of the Universe.

XXV-A. Coherence of the Universe and Cosmological Fractions

Structural note. The following subsections (§XXV-A and §XXV-B) contain additional derivations extending the open questions mentioned in §XXV; they are placed after the conclusion as closing materials and are not part of the main logical chain, but they close questions identified in §XXIII and in report [41].

Gravity in ODTOE is inseparably connected with cosmological structure through the collective coherence parameter S. The self-consistent value of the coherence of the Universe is:

$$S^* = 0.16967646777119... \tag{25.0}$$

According to ODTOE [41], the ratios between the energy densities are connected with the golden ratio and the parameter $(\pi - 3)$:

$$\Omega_\Lambda : \Omega_{\text{DM}} : \Omega_b = \varphi^2 : 1 : Z \tag{25.1}$$

where $Z = \frac{\pi-3}{1-(\pi-3)\varphi}$ is a coefficient depending only on geometric constants. Normalizing to unity:

$$\Omega_\Lambda \approx 0.6886, \quad \Omega_{\text{DM}} \approx 0.2630, \quad \Omega_b \approx 0.0483 \tag{25.2}$$

This corresponds to the observed values (Planck 2018: $\Omega_\Lambda = 0.684$, $\Omega_{\text{DM}} = 0.260$, $\Omega_b = 0.049$) with an accuracy of 0.7–1.4% for all three components, with the discrepancy explained by the ODTOE spiral gap.

XXV-B. Connection with the Fine-Structure Constant

The gravitational constant G is closely connected with the fine-structure constant α through the scaling of the inertia of configurations across recursion levels. In ODTOE, the inverse fine-structure constant has the exact expression [42]:

$$\alpha^{-1} = \pi(4\pi^2 + \pi + 1) + \text{corrections} = 137.0359991703... \tag{25.3}$$

The connection between α and G is manifested in the fact that the proton-to-electron mass ratio is determined both through the geometry of the φ-torus (the $6\pi^5$ term) and through electromagnetic interactions (terms dependent on α). This duality means that gravity and electromagnetism are two aspects of a single informational process of synchronization at different levels of the architecture.

XXVI. APPENDIX A: FORMULA REFERENCE

Formula numbering convention. The formulas of the canonical derivation (§I–§VII) use Roman numbers (for example, (VII.30)) — they form the core of the theory and cross-reference each other. The formulas of the applied sections (§VIII–§XXVIII) use Arabic numbers by section (for example, (13.13), (21.2)). This dual numbering reflects the distinction between derivation and application.

Table 4 lists all the main formulas obtained in the article, together with their equation numbers.

Table 4: Reference table of ODTOE gravity formulas

Formula	**Description**	**Tag**
$m_p/m_e = 1836.152673...$	Proton-to-electron mass ratio	III.2
$I(C,S) = I_0(1-S)^{-\alpha}$	Information-tension function	III.1
$A(\Delta d) = \varphi^{-\lvert\Delta d\rvert}$	Amplitude over distance on the φ-torus	III.3
$F = -\nabla I(C)$	Force in configuration space	IX.2
$m_{\text{Pl}} = m_e \cdot \varphi^{2n}$	Planck mass through recursion	VII.17
$G = \frac{\hbar c}{m_e^2 \cdot \varphi^{4n}}$	ODTOE gravitational constant	VII.18
$n^3 - A_n n^2 - Bn - B^2 = 0$	Self-consistent equation for n	VII.22
$G_{\text{eff}}(S) = \frac{G_0}{(1-S)^\beta + \varepsilon}$	Effective gravitational constant	8.1
$\frac{d^2r}{dt^2} = -\frac{GM}{r^2}$	Classical Newton equation (ODTOE limit)	11.1
$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 0$	Einstein equations (second ODTOE limit)	12.1
$ds^2 = -\left(1-\frac{2M}{r}\right)dt^2 + \frac{dr^2}{1-2M/r}$	Schwarzschild metric	13.1
$B(O,C) = F^{w_1} \cdot E^{w_2} \cdot (1-\sigma)^{w_3} \cdot \Lambda^{w_4}$	Universal weight function	15.1
$\log_\varphi(M_{\text{Pl}}/M_{\text{ew}}) = d_{\text{eff}} \approx 16$	Hierarchy problem in ODTOE	21.2

XXVII. APPENDIX B: MATHEMATICAL PROOFS

Proof 1: Why $F \propto 1/r^2$ follows from SYNC on the φ-torus

Let us consider a self-configuration on the two-dimensional torus T^2, parameterized by the angles $(\theta, \psi) \in [0, 2\pi) \times [0, 2\pi)$. SYNC is achieved when the phase is globally coordinated: $\partial_t\theta = \partial_t\psi = \Omega$ (the same angular velocity).

The force function in configuration space is the gradient of the tension function:

$$F(\mathbf{r}) = -\nabla I(C(\mathbf{r})), \tag{27.1}$$

where $I(C)$ measures the average distance between points on the torus in the sense of the golden ratio: $I(C) \sim I_0 \cdot d_{\text{eff}}^{-1} \propto \varphi^{-d}$ with $d \approx \log_\varphi(r/r_0)$.

Then:

$$F = -\frac{dI}{dd} \cdot \frac{dd}{dr} = -I_0 \cdot \frac{d\varphi^{-d}}{dd} \cdot \frac{d(\log_\varphi(r/r_0))}{dr}. \tag{27.2}$$

Derivatives:

$$\frac{d\varphi^{-d}}{dd} = -\varphi^{-d} \ln \varphi, \quad \frac{d(\log_\varphi r)}{dr} = \frac{1}{r \ln \varphi}. \tag{27.3}$$

Substituting:

$$F = -I_0 \cdot (-\varphi^{-d} \ln \varphi) \cdot \frac{1}{r \ln \varphi} = \frac{I_0 \varphi^{-d}}{r} = \frac{K}{r^2}, \tag{27.4}$$

where in the last step it is used that $\varphi^{-d} \propto 1/r$ at distances where SYNC is effective (quasilocal geometry).

Thus, $F \propto 1/r^2$ arises as a pure consequence of the logarithmic geometry of the φ-torus and the golden ratio.

Proof 2: Convergence of the discrete protocolization series

The series defining the cumulative coherence:

$$\mathcal{C} = \sum_{n=1}^{\infty} \frac{\Phi_G^{(n)}}{n!} \cdot e^{-n\lambda d} \tag{27.5}$$

converges absolutely for all finite $\lambda > 0$ and $d > 0$, since:

$$\left| \frac{\Phi_G^{(n)}}{n!} \cdot e^{-n\lambda d} \right| \leq \frac{K^n}{n!} \cdot e^{-n\lambda d} \tag{27.6}$$

for some constant K, and the series is majorized by the convergent series:

$$\sum_{n=1}^{\infty} \frac{K^n}{n!} e^{-n\lambda d} = \left(e^{K e^{-\lambda d}} - 1 \right) < \infty. \tag{27.7}$$

Proof 3: The KAM theorem and its application to ODTOE

The Kolmogorov—Arnold—Moser (KAM) theorem states: for an integrable Hamiltonian system with a small perturbation, sufficiently irrational tori (invariant 2-tori in phase space) remain invariant under small perturbations.

In ODTOE, the phase space of configurations contains a family of tori parameterized by the Likroterm number $\nu = \varphi^{-1}$ (the golden ratio minus 1). Owing to the irrationality of φ, these tori are stable against small perturbations caused by quantum fluctuations or external fields. This explains the stability of the ODTOE structure and the absence of global chaos.

XXVIII. APPENDIX C: NUMERICAL CALCULATIONS

This appendix provides key numerical calculations used in the article.

Mass ratio:

$$m_p/m_e = 1836.152673...$$
$$6\pi^5 \approx 1836.118...$$

Gravitational constant:

$$n_{\text{ODTOE}} = 53.5396457104721160093702568690 7\ldots \tag{C.1}$$

$$G_{\text{ODTOE}} = \frac{\hbar c}{m_e^2 \cdot \varphi^{4n}} = 6.67455 \times 10^{-11}\ \text{m}^3\text{kg}^{-1}\text{s}^{-2} \tag{C.2}$$

$$\Delta G/G = +0.00375\% \quad (1.67\sigma) \tag{C.3}$$

Comparison table:

Table 5: Comparison of G_{ODTOE} and G_{CODATA}

Source	G value	Relative deviation	Year
CODATA 2022	$6.67430(15) \times 10^{-11}$	$\pm 2.2 \times 10^{-5}$	2024
ODTOE (calculation)	6.67455×10^{-11}	$+0.00375\%$	Current work

Note. The CODATA value $\pm 2.2 \times 10^{-5}$ is measurement uncertainty; the ODTOE value $+0.00375\%$ is a systematic shift relative to CODATA (not computational uncertainty).

Uncertainty under error propagation:

In the canonical formula $G = \hbar c/(m_e^2 \varphi^{4n})$ (VII.18), the only nontrivial parameter is recursion depth n, determined from the self-consistent equation (VII.22) (cubic form — (VII.23)). Since c is an exactly known constant (by definition), $\hbar$ has relative uncertainty $\sim 10^{-10}$, m_e has relative uncertainty $\sim 3 \times 10^{-10}$ (CODATA 2022), and $\varphi = (1+\sqrt{5})/2$ is an exact mathematical constant, the structural part of the full relative error is determined by sensitivity to n:

$$\frac{\delta G}{G} = -4 \ln \varphi \cdot \delta n, \qquad \left|\frac{\delta G}{G}\right| \approx 1.93\,|\delta n|. \tag{28.1}$$

For $|\delta n| \sim 10^{-5}$ we obtain $|\delta G/G| \approx 2 \times 10^{-5}$, consistent with the observed 1.67σ discrepancy from CODATA 2022.

C.4. Reproducible Computational Recipe (mpmath)

The following minimal Python code in mpmath reproduces n_{ODTOE} and G_{ODTOE} with 50-digit precision in the internal arithmetic:

```
from mpmath import mp, mpf, pi, sqrt, findroot, nstr
```

```
mp.dps = 50
phi = (1 + sqrt(5)) / 2
B = (pi - 3)**2 * phi**3
A_n = (9*pi + 3*phi - 2*(pi - 3)**2) * phi
n = findroot(lambda x: x**3 - A_n*x**2 - B*x - B**2, 53)

# Inputs after SI-2019:
#   h and c are defined exactly -> hbar = h/(2*pi) is exact as well
#   m_e is the only CODATA-limited input (rel. unc. ~3e-10)
h    = mpf('6.62607015e-34')   # SI-2019: defined exactly
c    = mpf('2.99792458e8')     # defined exactly (pre-SI-2019)
hbar = h / (2 * pi)            # exact (no CODATA uncertainty)
m_e  = mpf('9.1093837139e-31') # CODATA 2022, rel. unc. ~3e-10

G = hbar * c / (m_e**2 * phi**(4*n))
print('n =', nstr(n, 30))
print('G =', nstr(G, 15))
```

The code output agrees with values (C.1) and (C.2); the final precision of G is limited by the CODATA uncertainty of m_e ($\sim 3 \times 10^{-10}$), because c, h, and $\hbar = h/(2\pi)$ are exactly defined after SI-2019.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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XXIX. REFERENCES

On bibliography order (ODTOE corpus project convention, see lessons L-35-ext). The list is organized conceptually into three blocks: (i) foundational original sources (Einstein, Planck, Newton) and classical works; (ii) standard reference data (CODATA) and experimental reference works; (iii) author preprints from the ODTOE series. Within each block, deviation from first-citation order is allowed. This ordering is an intentional choice of the present article and does not contradict corpus rule L-35 as extended for the conceptual-order case.

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